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Summary of Metallogeny

Renfrew County Area

by

S.B. Lumbers

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CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE–Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in co-operation with the Coal Association of Canada.

ABSTRACT

This report and accompanying maps provide a geological framework to relate regional petrological and tectonic features to known mineral deposits within a 9300 km² area of the Grenville Province in southeastern Ontario. The area (Figure 1) lies within Latitudes 46°N and 45°N, Longitudes 78°W and 76°W, and is bounded to the northeast by the Ottawa River.

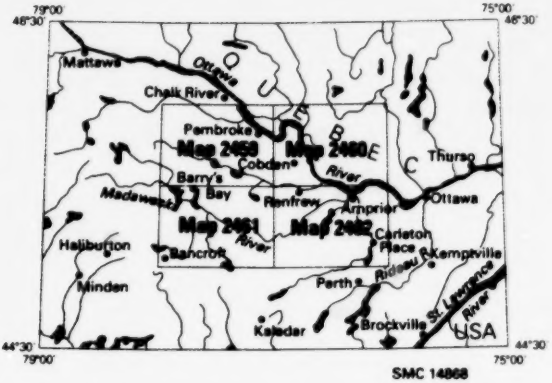

Figure 1–Key map showing location of Renfrew County map-area.

The map-area constitutes a 135 km section across the central part of the Grenville Province and straddles two major supracrustal accumulations of contrasting age and lithology. The older accumulation, consisting mainly of clastic siliceous metasediments and deposited between 2.5 and 1.8 Ga ago, extends into the northern part of the map-area. The younger accumulation, which includes rocks commonly referred to as the "Grenville Supergroup" and was deposited between 1.5 and 1.28 Ga ago, dominates the southern part of the map-area. This accumulation consists mainly of carbonate metasediments, subordinate clastic siliceous metasediments, and local metavolcanics. The older accumulation was intruded by the Algonquin Batholith, which dominates the central and northern parts of the map-area. Composed of anorthosite suite rocks, the batholith was emplaced between 1.5 and 1.4 Ga ago, and supracrustal rocks of the younger accumulation rest unconformably upon its southwestern flank. The base of this accumulation consists of a coarse clastic sequence locally containing large clasts lithologically similar to the batholith. Between 1.3 and 1.0 Ga ago, a large variety of plutonic rocks were emplaced within the carbonate-rich younger accumulation. In approximate order of decreasing age, the plutonic rock suites are: 1) biotite diorite suite; 2) anorthosite suite; 3) quartz monzonite suite; 4) alkalic suite; and 5) syenite-monzonite suite.

Between 1.15 and 1.0 Ga ago, high rank regional metamorphism converted most of the rocks of the map-area into intensely deformed and coarsely recrystallized gneisses. During this metamorphism, the batholithic bodies became diapiric toward the overlying supracrustal rocks causing tectonic deformation of the plutonic rocks and subhorizontal gneissic foliation and recumbent folding in the supracrustal rocks for tens of kilometres around the Algonquin Batholith. Metamorphic mineral assemblages in the gneisses are indicative of middle to upper almandine amphibolite facies; locally, a few highly strained intrusive bodies contain granulite facies mineral assemblages. Some intrusions of the quartz monzonite, alkalic, and syenite-monzonite suites, and granite pegmatite dikes were emplaced during the waning stages of regional metamorphism. During this time, rocks of the alkalic suite, which are concentrated close to the unconformity marking the base of the younger accumulation, underwent widespread fenitization. Following termination of the high rank regional metamorphism, the map-area underwent uplift, faulting, mafic intrusive activity, erosion, and deposition of lower Paleozoic sedimentary rocks.

The Ottawa-Bonnechere Graben cuts eastward across all but the southwestern part of the area and is marked by prominent fault systems and subsidiary grabens, swarms of diabase dikes, zones of localized fenitization, and small mafic to ultramafic stocks.

Most mineralization of economic importance is confined to the younger accumulation of Precambrian sedimentary rocks where, in the past, deposits of apatite, beryl, clay, corundum, feldspar, graphite, iron, lead, magnesium, mica, pyrite, stone, and strontium were mined or quarried. Present production is confined to clay, magnesium, rose quartz, beryl, and stone. Sand and gravel are quarried throughout the area for local construction purposes.

Summary of Metallogeny

Renfrew County Area

by

S.B. Lumbers[1]

INTRODUCTION

This report presents a summary of the regional petrologic and tectonic features of a 9300 km^2 area in the Grenville Province of southeastern Ontario and attempts to relate these features in space and time to known mineral deposits within the area. The map-area constitutes a 135 km section across the central part of the Grenville Province of Ontario and connects the geology of the older, predominantly Middle Precambrian northwestern portion with the younger, predominantly Late Precambrian southeastern portion (Ayres *et al.* 1971). The present study combined with other work by the author in the northwestern and southeastern parts of the Grenville Province and recent and past work by others in the Georgian Bay and southeastern portions now allow a preliminary statement to be made concerning the stratigraphic and tectonic framework of the entire Grenville Province of Ontario. Such a framework is essential to metallogenic studies, and the more refined the framework, the more direct use it has in mineral exploration. The refinement process is long and exacting, especially in a region as geologically complex as the Grenville Province, so that occasional progress reports such as the present one are desirable to make use of accumulated knowledge and data.

The map-area includes all but the extreme northern townships of Renfrew County, and it lies between Latitudes 46°N and 45°N, and between Longitudes 78°W and 77°W and is bounded to the northeast by the Ottawa River. Small portions of the District of Nipissing, the Counties of Hastings, Lennox and Addington, Frontenac, and Lanark, and the Regional Municipality of Ottawa-Carleton are also included within the area. Major centres of population are Petawawa, Pembroke, Cobden, Foresters Falls, Renfrew, Arnprior, Calabogie, Eganville, Golden Lake, Killaloe Station, Wilno, Barry's Bay, Madawaska, Combermere and Quadeville. Good access to most of the area is provided by numerous township roads, provincial highways, and main and branch railway lines of the Canadian National Railways and Canadian Pacific Railway. The northern part of the area includes portions of Algonquin Provincial Park and Canada Forces Base, Petawawa, and travel in these areas is regulated.

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[1]Curator of Geology, Royal Ontario Museum. Manuscript accepted for publication by the Chief Geologist, Ontario Geological Survey, Nov. 13, 1979. This report is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

Geologically, the area can be subdivided into two portions of contrasting age and lithology along a northeasterly trending zone of coarse clastic metasediments (see Figure 2). The northwestern portion is dominated by anorthosite suite rocks of the Algonquin Batholith which intruded Middle Precambrian[1] metasediments. The southeastern portion is composed of a lithologically complex assemblage of Late Precambrian supracrustal and plutonic rocks, all younger than about 1.5 Ga (billion years). Most mineralization of economic importance is confined to the southeastern portion where, in the past, deposits of apatite, asbestos, beryl, clay, corundum, feldspar, graphite, iron, lead, magnesium, mica, pyrite, stone and strontium, were mined or quarried. The only mineral production from the northwestern portion consists of small quantities of feldspar and mica mined from late granite pegmatite dikes cutting rocks of the Algonquin Batholith, and stone quarried from rocks of the batholith for local construction purposes. Present production, all from deposits within the southeastern portion, is confined to clay (The Dochart Brick and Tile Company Limited of Arnprior), magnesium produced from dolomitic marble in Ross Township by Chromasco Limited, rose quartz and beryl obtained from pegmatite bodies in Lyndoch Township by Wal Gem Lapidary Company of Quadeville, and stone produced from outliers of Paleozoic limestone near Arnprior by Smith Construction Company and Cavanagh Construction. Sand and gravel are quarried throughout the area for local construction purposes.

Data for this study were obtained from: 1) geological mapping by the author over five field seasons between 1974 and 1978, 2) previous work (see below); 3) work on mineral deposits by the Mineral Deposits Section of the Ontario Geological Survey; and 4) petrologic and geochemical studies carried out by the author and others at the Department of Mineralogy and Geology, Royal Ontario Museum. Petrologic and geochemical studies remain in progress. Data gained do date are sufficient to allow generalized subdivision of the rocks, and synthesis of the regional geology. Presentation of modal and chemical data, and discussions of petrogenesis must await completion of the studies in progress and will be published at a later date.

Acknowledgments

The author was assisted in the field by K.G.P. Carrier, by D.L. Dillon, and by V.M. Vertolli. Mr. P. Mark assisted the author in the field during portions of two field seasons, and B. Podstawskyj assisted during part of one field season. G.D Gauthier and R.S. Simon compiled field data and assisted in map compilation. Mr. Vertolli carried out independent mapping, assisted in various phases of the laboratory work and map compilation, and drafted the manuscript maps. Several staff members of the Department of Mineralogy and Geology, Royal Ontario Museum, were helpful in various ways: R.I. Gait, F.J Wicks, B.D. Sturman, R.A.J. Ramik, and Mrs. C. Peat provided mineral identifications by X-ray

[1]For purposes of this report, Precambrian time is subdivided into three units: Early, Middle and Late. The time boundary between Early and Middle is 2.5 Ga (billion years) and between Middle and Late 1.6 Ga.

diffraction and optical techniques; T.E. Krogh supplied geochronological data; and H. Sheriff prepared numerous thin section. W.M. Schwerdtner of the Department of Geology, University of Toronto, supplied much-valued discussions on aspects of the structural geology of the map-area. S.G. Themistocleous, A.C. Colvine, T.R. Carter, and J.B. Gordon of the Ontario Geological Survey provided the author with geological data and rock specimens that they obtained within the map-area.

Many residents and resort operators within the map-area, too numerous to name individually, were helpful in many ways, and the author would like to express his appreciation to them all. Mr. J. Simpson, Superintendent, Algonquin Provincial Park and Mr. L. Bronson, District Manager, Pembroke, Ministry of Natural Resources, were particularly helpful in arranging for the loan of equipment and allowing access to certain portions of the map-area where travel is regulated. Military personnel at Canada Forces Base, Petawawa, were very cooperative in allowing the author access to the base to carry out geological mapping.

This work was directed by the Precambrian Geology Section, Ontario Geological Survey, Ministry of Natural Resources, under the Mineral Resources Assessment Project, Pembroke-Renfrew Region, jointly funded by the Ministry of Treasury and Economics, Ontario, and the Department of Regional Economic Expansion, Canada, under the Community and Resource Development Subsidiary Agreement.

Previous Work

Geological investigations have been carried out in various parts of the map-area for over 100 years. Previous workers experienced great difficulty in subdividing and recognizing the primary lithologies of the Precambrian rocks because these rocks were subjected to Late Precambrian high rank regional metamorphism and are gneissic with only vestiges of their primary lithologies remaining. Several advances in interpreting the petrogenesis of such rocks have been made in recent years, but most of the previous workers did not have the advantage of this knowledge. They were therefore greatly hindered in attempts at synthesizing the geology which is so crucial to metallogenic studies.

The earliest work was of a general reconnaissance and exploratory nature performed by geologists of the Geological Survey of Canada between 1850 and 1930 (see Satterly 1945, p.3-4). Since 1930, several parts of the area have been mapped at various levels of detail by Kay (1942), Quinn (1952), Quinn *et al.* (1956), Hewitt (1954), Livingstone *et al.* (1974), and Themistocleous (1978; 1979). Satterly (1945) carried out reconnaissance geological studies and made a regional compilation of the geology of most of the present map-area during examination of mineral deposits in Renfrew County in 1943. Until now, Satterly's work was the only regional compilation of the Renfrew area available, and over the years, his work has proven invaluable to anyone interested in the geology and mineralization of Renfrew County.

Several reports have been published concerning mineral deposits in the area, and these are summarized in Satterly (1945), Carter *et al.* (1979), Vos and Storey (1979), and Gordon and Masson (in preparation). Published geophysical

and geochemical surveys covering either all or portions of the map-area consist of: 1) aeromagnetic maps (GSC 1947; 1950; 1951; 1952a; 1952b; 1952c; 1953; 1955a; 1955b; 1962a; 1962b; 1962d); 2) airborne gamma-ray spectrometry surveys (GSC 1976); 3) geochemical reconnaissance surveys (OGS-GSC 1977); and 4) gravity surveys (Earth Physics Branch 1971).

The northern extremity of Renfrew County (Townships of Clara, Maria, Head, Rolph, and portions of Wylie and Buchanan) are not covered by this report but were mapped by the author between 1973 and 1975 (Lumbers 1976). Most of the region adjacent to the southern and southwestern parts of Renfrew County was mapped by Hewitt (1955), Hewitt and James (1956), Evans (1964), Lumbers (1964; 1967), Smith (1958), Peach (1958), and Reinhardt (1973).

Present Geological Survey

Most of the northwestern portion of the area, where geological units are relatively large, was traversed at 1 mile (1.6 km) intervals. Most of the southeastern portion of the area, where geological units are relatively small, was traversed at ½ mile (0.8 km) intervals. In addition, all lakes, streams, roads, railways, power lines, and other places containing clean outcrops relatively free of lichen and other vegetal cover were mapped in detail. Such outcrops allow the rocks to be accurately classified and described, and they provide most of the data for geological interpretation and synthesis. After examination on the ground, some well exposed areas were flown by aircraft at low altitudes to refine geological contacts.

Geological data were plotted in the field on transparent plastic film fitted to air photographs close to a scale of 1 inch to ½ mile (1:31 680). This data was transferred by sketchmaster to appropriate map sheets of the Forest Resources Inventory of the Ontario Ministry of Natural Resources reduced photographically to 1 inch to ½ mile (1:31 680). Final geological interpretation was made on these sheets, and then the sheets were reduced photographically to 1:63 360. The generalized geology and outcrop areas were transferred to 1:63 360 base maps prepared by the Cartography Section, Surveys and Mapping Branch, from maps of the Forest Resources Inventory. Final coloured maps (Maps 2459, 2460, 2461, 2462, back pocket) have been published on a scale of 1:100 000. During the field work, any necessary topographic additions and corrections were made to the manuscript map by the author.

Liberal use was made of data collected and published by previous workers in the area. Original manuscript maps, field notes, and other data collected by Satterly (1945) and Hewitt (1954) were made available to the author by the Ontario Geological Survey, and this data proved invaluable in compiling the geology. Field data and original interpretive maps with specimen locations compiled during this study are on file at the Department of Mineralogy and Geology, Royal Ontario Museum, and all specimens collected during the field work and their thin sections form part of the Department's petrology collection. Geologists interested in inspecting this data and the specimens can do so by contacting the Department for an appointment.

Topography and Rock Exposure

On the geological maps (back pocket), major drift-covered areas containing no outcrop are indicated by a stipple pattern. Elsewhere, rock exposure varies greatly and ranges between about 5 and 80 percent.

Paleozoic rocks, which for the most part are flat lying and are preserved as infaulted outliers within the Ottawa-Bonnechere Graben (Kay 1942), show the poorest exposure. Most of the outcrop areas of these rocks shown on the maps consist of either flat bedding surfaces partly obscured by a thin soil mantle supporting a scrubby vegetal growth dominated by juniper shrubs, or concentrations of large blocks of Paleozoic rocks up to several metres in size lying on or near flat bedding surfaces. Most of the outcrops in Westmeath Township, inland from Ottawa River, are characterized by concentrations of large blocks, but elsewhere outcrop areas are mainly flat bedding surfaces. The only stratigraphic sections present are either in roadcuts and quarries, or along streams and lakeshores. The thickest sections exposed are along the Ottawa River, and these rarely exceed 10 m in height.

The Precambrian rocks are cut by numerous normal faults trending mainly west-northwest. Most of the faults are marked by prominent scarps and narrow to broad valleys which host the major streams draining highland areas centred over the Algonquin Batholith and the region southwest of the Mount St. Patrick Fault. Many of the valleys channelled melt waters toward the Ottawa Valley during deglaciation, so that near the Ottawa River and in areas where the valleys broaden because of secondary graben development, extensive deposits of sand and gravel obscure the bedrock. Waters of the Champlain Sea flooded the Ottawa Valley as far north as Pembroke and left extensive deposits of marine clay upon the bedrock in low lying areas along the Ottawa Valley. Near junctions of major valleys draining highland areas with the Ottawa Valley, extensive deltaic deposits formed, further obscuring the bedrock. During deglaciation, intrusive rocks between Pembroke and Arnprior within the Ottawa Valley formed topographic highs, so that much of the glacial and other debris was washed from them by melt waters and wave action of marine waters leaving them well exposed today. Intervening areas of carbonate metasediments are generally poorly exposed.

The Algonquin Batholith is characterized by rough to irregular topography with numerous high hills commonly marked by steep to gentle slopes facing northward toward the direction of the advancing ice-sheet and steep rocky slopes and cliffs facing southward on the leeward side of the advancing ice-sheet. The northerly slopes are largely covered by glacial drift. Numerous areas within the batholith are marked by subhorizontal gneissic foliation which produces relatively flat hills partly surrounded by steep rocky slopes and cliffs and intervening, narrow, drift-covered valleys. Excellent exposures are generally present near most of the fault scarps and along most of the lakes and streams.

The highland area of Precambrian rocks southwest of the Mount St. Patrick Fault is generally well exposed where intrusive rocks predominate, but many of the areas underlain mainly by carbonate rocks are poorly exposed. Excellent exposures of carbonate rocks are present in the vicinity of Black Donald

and Centenial Lakes in Brougham and Matawatchan Townships where these rocks are in long ridges striking parallel to the gneissic foliation in the metasediments. The ridges locally contain thin units of siliceous metasediments and intrusive rocks relatively resistant to erosion. Rock exposure has also been increased in this area by flooding of the Madawaska River due to hydro electric power dam construction and by forest fires and logging operations which allowed much of the soil cover in high rocky ridges to be removed by erosion.

REGIONAL GEOLOGICAL SETTING

The Grenville Province of Ontario is underlain by a variety of supracrustal and plutonic rocks that reflect a long, complex geological history spanning more than 2Ga. Much of this history is reflected by rocks of the map-area, but interpretation of the history is difficult because most of the rocks were subjected to Late Precambrian high rank regional metamorphism which culminated between about 1.3 and 1.0 Ga ago (Lumbers 1967; 1978) and which converted nearly all the rocks into markedly recrystallized and deformed gneisses. This metamorphism, which is commonly referred to as the "Grenvillian Orogeny", affected the entire Grenville Province of the Canadian Shield and allows the Grenville Province to be recognized as a unique, primary subdivision of the shield. Major geological features forming the basic framework of the Grenville Province in Ontario are shown in Figure 2 (Chart A, back pocket), together with the boundaries of the map-area.

In Ontario and for an unknown distance northeastward across the interprovincial boundary into Quebec, high metamorphic rank gneisses of the Grenville Province are separated from relatively low rank metamorphic rocks of the Superior and Southern Provinces by a fault zone, the Grenville Front Boundary Fault, which defines the northwestern boundary of the Grenville Province in Ontario (Figure 2). This fault is near the northwestern margin of the Grenville Front Tectonic Zone, details of which are summarized in Lumbers (1978).

Southeast of the boundary fault, the Grenville Province contains two geosynclinal supracrustal accumulations of contrasting age and lithology. The older accumulation, deposited during the Middle Precambrian between 2.5 and 1.8 Ga ago, is confined to the northern two-thirds of the province and consists mainly of clastic siliceous metasediments deposited in deep water below wave-base (Figure 2). Near the northwestern margin of the Grenville Province, the older accumulation rests unconformably upon Early Precambrian rocks extending across the boundary fault into the Grenville Province from the Superior Province (Figure 2 and Lumbers 1978). The base of this accumulation is marked by a coarse clastic sequence (Figure 2) deposited largely in deep water below wave-base, probably in a submarine fan environment (Lumbers 1978). The coarse facies gradually changes into thinly bedded, medium-grained metagreywacke and meta-argillite which could represent a facies change to outer fan turbidites. These rocks were deposited in a linear depression or trough along the northwestern margin of the Grenville Province and are correlative with the lower part of the Huronian Supergroup in the Southern Province (Lumbers 1978). South of the trough metasediments, the supracrustal rocks contain several major units of moderately- to well-sorted arkose, subarkose,

orthoquartzite, aluminous clay-rich material, and rare iron formation and marble deposited in a nearshore environment under the influence of wave action. These units are intercalated with thick sequences of impure metasandstone and meta-argillite containing much more potassic feldspar than the deep water facies of the trough. If these rocks are part of the trough sequence, then they mark an important change in the paleogeography of the developing Middle Precambrian geosynclinal accumulation. Alternatively they could represent a younger Middle Precambrian sequence deposited upon the deep water facies of the trough. Impure metasandstone and meta-argillite of this possibly younger sequence extends into the northern part of the map-area where they were intruded by the Algonquin Batholith (Figure 2, back pocket).

The younger accumulation, which includes rocks commonly referred to as the "Grenville Supergroup", is present mainly in the southern third of the Grenville Province of Ontario (Figure 2) and consists mainly of carbonate metasediments, subordinate clastic siliceous metasediments, and locally thick sequences of metavolcanics. The Algonquin Batholith, which intruded rocks of the older accumulation, is overlain unconformably by rocks of the younger accumulation along its southern flank and at least part of its western flank. Composed of anorthosite suite rocks, the batholith underlies the central part of the Grenville Province, and preliminary geochronological data suggest that its major phases are between 1.4 and 1.5 Ga old (Krogh and Davis 1969b; Lumbers and Krogh 1977). The batholith narrows greatly to the northeast and may be linked to similar batholiths under the St. Lawrence Platform and in the Grenville of Quebec (Schwerdtner and Lumbers 1980). Moreover, the batholith appears to be part of a major magmatic event of continental proportions, about 1.4 to 1.5 Ga old, that has been postulated throughout a broad area extending from Labrador to Southern California (Silver *et al.* 1977).

The base of the younger accumulation is marked by a basal arkose and coarse clastic sequence (Figure 2) which has been studied only in the map-area, but which has been traced in a crude reconnaissance fashion by the author to the west as far as Lake Muskoka. The sequence contains local thin units of marble, calcareous and siliceous shaly metasediments, and orthoquartzite, and it undergoes a facies change southeastward across strike into the carbonate rocks dominating the younger accumulation. This carbonate marine basin can be traced across strike for over 240 km southeast into the Adirondack region of New York State, and along strike to the east it crosses the Ottawa River where it deflects northwestward for several tens of kilometres parallel to, and east of, the river. Major volcanism occurred within the basin about 1.3 Ga ago (Lumbers 1967), but the volcanism appears to be restricted to the northwestern part in Ontario. The base of the volcanic sequence is not exposed, but the earliest recognizable volcanism was basaltic and formed shield volcanic complexes which later evolved into strato volcanoes (Lumbers 1967). Volcanic highlands were eroded supplying volcaniclastic detritus that formed aprons of turbidite deposits about the eroded highlands. The carbonate facies was deposited both during and after the volcanism so that this facies is intercalated with most of the volcanic and volcaniclastic rocks (Lumbers 1967). The thickest part of the exposed volcanic sequence is in the Bancroft-Madoc area southwest of the map-area, and this portion coincides with the only region of low rank metamorphism so far identified in the Grenville Province of the Canadian Shield (Lum-

bers 1967). Geophysical data suggest that the volcanic rocks extend for an unknown distance southwest of the Bancroft-Madoc area beneath the Paleozoic cover of the St. Lawrence platform. To the northeast of the Bancroft-Madoc area, the volcanic rocks become scarce and appear to be absent near the Ottawa River south of Ross Township in the map-area. No basement rocks have been unequivocably identified within the basin, and it appears that the Algonquin Batholith was emplaced near the margin of a Middle Precambrian continental mass. The oldest plutonic rocks identified within the basin are about 1.28 Ga old (Lumbers 1967), and this age provides an upper limit for the interval involved in deposition of the younger accumulation.

A second basin of supracrustal rocks possibly correlative with those of the carbonate-rich basin southeast of the Algonquin Batholith extends northward from southeastern Georgian Bay to south of Lake Nipissing (Figure 2). These supracrustal rocks have been only partly mapped on a crude reconnaissance scale, but they appear to be characterized by abundant shaly metasediments containing intercalated thin marble units; metavolcanics have been noted at a few localities.

Most of the plutonic rocks cutting the older accumulation belong to the anorthosite suite and are Late Precambrian, ranging in age from about 1.5 to 1.1 Ga old (Lumbers 1975; Lumbers and Krogh 1977). The only older plutonic bodies consist mainly of quartz monzonite and minor granodiorite emplaced mainly within the Grenville Front Tectonic Zone and the deep water turbidite deposits during the Middle Precambrian, about 1.7 Ga ago (Figure 2 and Lumbers 1978). Between 1.3 and 1.0 Ga ago, a large variety of plutonic rocks were emplaced within the carbonate-rich younger accumulation southeast of the Algonquin Batholith. Most of the plutonic rocks can be divided into suites without prejudgment as to genetic implications, with each suite consisting of rocks consistently associated in space and time. Moreover, the suites are characterized by certain chemical features, such as high alkali contents, or high soda and low potassium contents. More data are needed to prove that rocks comprising each suite are comagmatic, and some of the suites may be related genetically. A few of the suites recognized here, such as the biotite diorite suite, have also long been recognized within orogenic belts of diverse ages on a global scale (see Barth 1952). Subdivision of the plutonic rocks into suites is also advantageous from the point of view of mineral exploration, because certain important relationships emerge with respect to associated mineral deposits (Lumbers 1964).

Five major plutonic rock suites are recognized, and all five are present in the map-area. Considerable petrologic data are necessary to assign a plutonic body to a particular suite, and unfortunately, such data are not available for all the plutonic bodies within the carbonate-rich accumulation. A generalized distribution of the various suites for which data are available is shown in Figure 3 (Chart A, back pocket). In approximate order of decreasing age, the following suites are recognized: 1) biotite diorite suite characterized by abundant dioritic rocks, tonalite, and sodic granitic and syenitic rocks, chiefly trondhjemite, granodiorite, albite granite, albite syenite; 2) anorthosite suite consisting of anorthositic and tonalitic rocks and associated monzonitic and syenitic rocks (Lumbers 1975); 3) quartz monzonite suite characterized by abundant quartz monzonite and only minor phases of other calc-alkalic intrusive rocks; 4) alkalic suite dominated by alkalic syenite and granite, but containing minor

mafic alkalic rocks and nepheline syenite; and 5) syenite-monzonite suite characterized by abundant calc-alkalic syenite and minor monzonite, quartz monzonite, tonalite and gabbro. Geochemical and geochronological investigations of the various rock suites in progress should aid in understanding their petrogenesis and refine their subdivision as outlined here. The alkalic suite is confined mainly to a major complex near the northwestern margin of the Late Precambrian supracrustal accumulation, but small intrusions of the suite also occur elsewhere (see Figures 2 and 3). Minor phases of anorthosite suite rocks are common in the major alkalic complex and this spatial association of the two suites has also been recognized to the north of the Algonquin Batholith in predominantly anorthosite suite intrusions in the Burwash and Mattawa-Deep River areas (Lumbers 1975; 1976a; 1976b). Perhaps a genetic link exists between the two suites (Lumbers 1976b). Anorthosite suite rocks are also spatially associated with some quartz monzonite suite intrusions in North Canonto and Blithfield Townships in the map-area. Further work may also show a genetic link between these two suites.

The metamorphic history of the Grenville Province is difficult to determine in detail because the late high-rank regional metamorphism effectively obliterated evidence of any earlier metamorphic events. Neverthless, some evidence suggests that the older supracrustal accumulation near the northwestern margin of the Grenville Province was affected by the Penokean event that regionally metamorphosed rocks of the Southern Province near Sudbury and to the west between 2.16 and 1.8 Ga ago (Lumbers 1978). This metamorphism varied in intensity but rarely exceeded the temperature and pressure conditions of the lower almandine amphibolite facies. Mineral assemblages developed in the Grenville gneisses during the late high-rank regional metamorphism are most indicative of temperature and pressure conditions existing in the middle to upper almandine amphibolite facies. Locally within a few highly strained granitic intrusions in the younger accumulation southeast of the Algonquin Batholith, mineral assemblages suggestive of granulite facies temperature and pressure conditions exist. Many of the metamorphosed monzonitic and syenitic rocks of the anorthosite suite contain hypersthene, but the presence of this mineral is not indicative of granulite facies metamorphism of these rocks as claimed by some geologists (see Lumbers 1971; 1975). During the late metamorphism, the Algonquin Batholith was reactivated and became diapiric toward the overlying rocks causing most of the tectonic deformation, not only of rocks of the batholith, but also of rocks of the two supracrustal accumulations (Schwerdtner and Lumbers 1980). Numerous oval diapiric structures outlined by lithology and replete with subhorizontal flattening genissosity are present within the batholith (see Map 2459, back pocket). The long diameter of the batholith parallels the overall trend of the folded unconformity marking the base of the younger supracrustal accumulation (see Figure 2). This diapirism accounts for subhorizontal gneissic foliation and recumbent folding dominant in the supracrustal rocks for tens of kilometres around the batholith.

The latest tectonism to affect the Grenville Province is related to activity along the Ottawa-Bonnechere Graben (Figure 4, Chart A, back pocket) which crosses the Grenville Province westward along the Ottawa and Mattawa Valleys and continues westward across the Grenville Front Tectonic Zone to join the Murray Fault System south of Sudbury. The graben, which is part of the St.

Lawrence Rift System (Kumarapeli and Saull 1966) was probably initiated early in Early Precambrian time (Lumbers 1980) and has remained active to the present eastward from Lake Nipissing. The graben is marked by prominent fault systems on the north (Mattawa River Fault and Ottawa System, Figure 4), by swarms of diabase dikes and a prominent zone of normal faulting and small subsidiary grabens on the south, and widespread zones of localized fenitization. Most of the diabase dikes postdate the late high rank regional metamorphism in the Grenville Province, but some were intruded while this metamorphism was on the wane. Lamprophyre and trachyte dikes, small peridotite bodies, one late gabbro body, and a few alkalic rock-carbonatite complexes and cryptoexplosion structures, all ranging in age from Late Precambrian to early Cambrian, are locallized within the graben. All but the southern part of the map-area, southwest of the prominent zone of faulting extending west-northwest from south of the Mount St. Patrick Fault through the northern part of Kamaniskeg Lake and Aylen Lake (Maps 2459, 2461, 2462, back pocket) lies within the graben. Representatives of most of the various late intrusions associated with the graben are present in the map-area.

GEOLOGICAL SUMMARY OF THE MAP-AREA

Figure 5 summarizes the sequence of events recorded by rocks of the map-area, and the relationship of these events in space and time to known mineralization. Mineralization aspects will be discussed below after the rocks comprising the events are briefly summarized in this section. In positioning events shown in Figure 5 in a time framework, most weight was given to relative age relationships visible in the field, particularly cross-cutting relationships shown by plutonic rocks and ages of plutonic rocks relative to the late high rank regional metamorphism. Available geochronological data on the rocks involved, chiefly from Silver and Lumbers (1966), Krogh *et al.* (1968), Krogh and Hurley (1968), Krogh and Davis (1969a), and unpublished data by Krogh, have been obtained mainly from portions of the plutonic rock suites and metavolcanics outside the map-area and are too incomplete and preliminary in nature to provide more than a general time reference. Thus, most events cannot be given precise time limits, but the duration and overlap of events can be estimated. Events of regional nature recorded by rocks both within and outside the map-area are shown by heavy lines. The light lines indicate events that are either restricted in their distribution, such as faulting and associated intrusive activity along the Ottawa-Bonnechere Graben, or inferred, such as metamorphism of the Middle Precambrian rocks as a result of intrusion of the Algonquin Batholith.

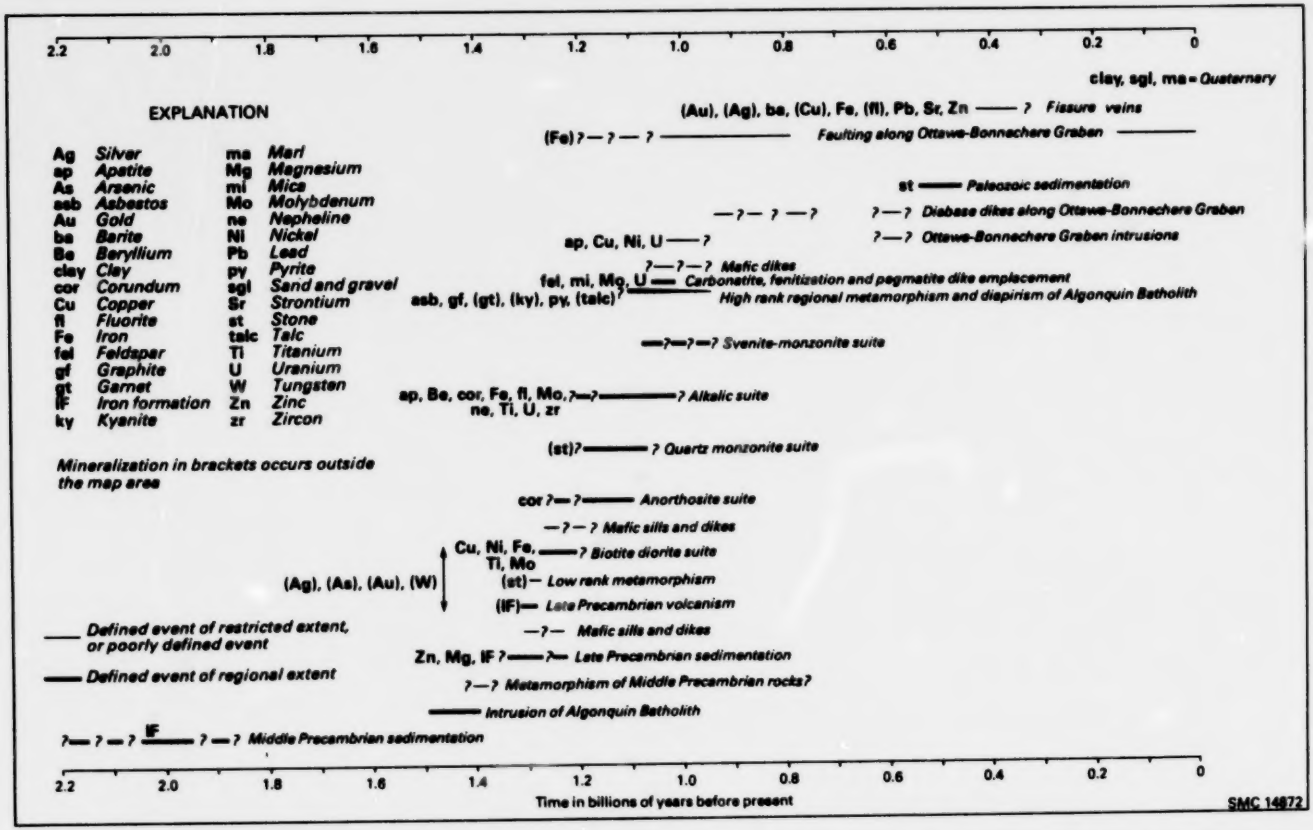


Figure 5–Sequence of events recorded by rocks of the map-area, and the relationship of these events in space and time to known mineralization.

Middle Precambrian

Metasediments

The oldest rocks exposed in the map-area consist of Middle Precambrian metasedimentary gneisses derived from two main types of sequences: 1) intercalated impure sandstone, feldspathic sandstone, and siliceous and calcareous mudstone, and 2) sequences dominated by siliceous mudstone containing intercalated, thinly bedded impure sandstone, feldspathic sandstone, and siliceous and calcareous mudstone. Metamorphism converted the calcareous mudstone of both sequences into rocks rich in amphibole, quartz, plagioclase, and minor diopside, epidote, and biotite; marble is absent but is associated rarely with both sequences in the Mattawa-Deep River area to the north of the map-area (Lumbers 1976a). The sandstones generally contain abundant potassic feldspar in marked contrast to sandstones of the trough metasediments mentioned above in the "Regional Geological Setting" section. Near the east end of Grand Lake in southwestern Stratton Township (Map 2459, back pocket), the metasediments are mainly feldspathic and quartzose sandstone with a few intercalated thin units up to 30 cm thick of a metasediment possibly derived from iron formation. This metasediment is muscovite-biotite-oligoclase-quartz gneiss with up to 50 percent magnetite concentrated in dismembered micaceous layers up to 3 cm thick and separated by slightly thicker quartz-rich layers.

The age of the Middle Precambrian metasediments is poorly known. Regionally, they are intruded by plutonic rocks as old as 1.7 Ga (Lumbers 1978), and in the map-area, they are cut by rocks of the Algonquin Batholith emplaced between 1.4 and 1.5 Ga ago. As discussed above, the metasediments may be younger than Middle Precambrian supracrustal rocks near the northwestern margin of the Grenville Province that are correlative with the lower part of the Huronian Supergroup deposited between about 2.5 and 2.2 Ga ago. In Figure 5, the age is estimated at about 2 Ga with a large margin of uncertainty.

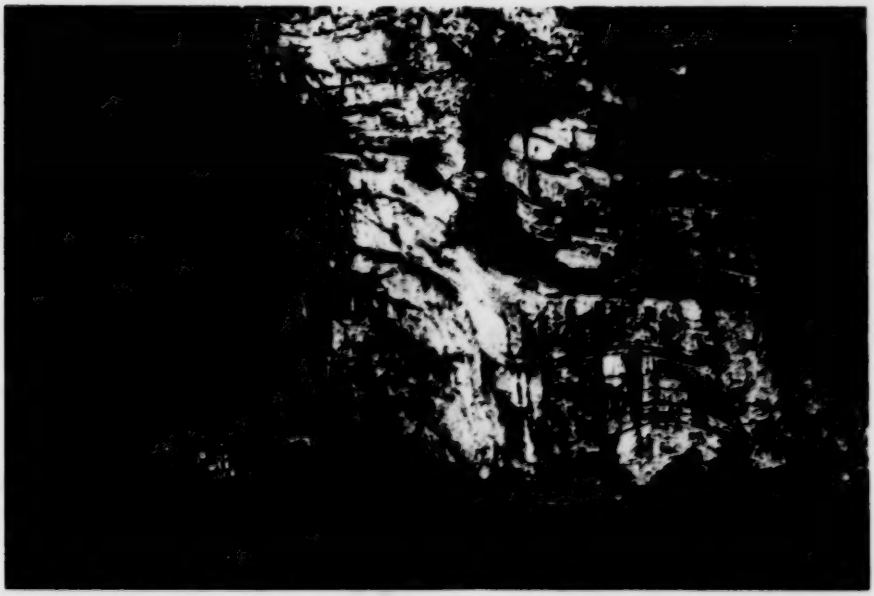
Late Precambrian

Algonquin Batholith

Rocks of the Algonquin Batholith are highly strained and metamorphosed so that for the most part they consist of augen gneiss and gneiss containing prominent layering. Nevertheless, well exposed outcrops generally reveal isolated, slightly gneissic phases displaying relict primary textures and, rarely relict primary feldspar indicating that the gneisses were originally massive igneous rocks. Lithologically, the batholith consists of anorthosite suite rocks (map-units 2 to 4), mainly gneissic quartz monzonite, with several large units of monzonitic and syenitic rocks and scattered small units of anorthositic and related mafic rocks. The southern part of the batholith between Bark Lake and

southwestern Hagarty Township (Map 2461, back pocket) is relatively rich in gneissic tonalite. Petrographically, the rocks are similar to anorthosite suite rocks in the Burwash area (Lumbers 1975).

Most of the anorthositic rocks are relatively mafic and contain between 20 and 30 percent ferromagnesian minerals (mainly biotite and amphibole, but some phases contain clinopyroxene). Plagioclase ranges in composition between about An_{25} and An_{45}. North of Golden Lake and east of Pembroke, relatively small units containing anorthositic rocks are composed largely of gneissic diorite. Gneissic tonalite is essentially a quartz-ferromagnesium-sodic andesine rock containing 10 to 20 percent quartz, 15 to 40 percent biotite, amphibole, and, rarely, clinopyroxene, and accessory garnet, potassic feldspar, iron-titanium oxide minerals, apatite, and zircon. Gneissic quartz monzonite in the vicinity of tonalitic, anorthositic, and dioritic units is rich in highly stretched xenoliths of amphibolite and tonalitic rocks and contains up to 15 percent amphibole as the chief ferromagnesian mineral. Such xenolith-rich phases also occur locally where large units of the more mafic phases are absent. Where the xenoliths are minor or absent in the quartz monzonite, biotite is the chief ferromagnesian constituent. Where intensely sheared, the xenolith-rich quartz monzonite is extremely heterogeneous and except for a larger grain size and typical augen structure, it resembles some of the Middle Precambrian met-



OGS 10 285

Photo 1–Cliff face about 9 m high on Barron River 2 km west of the east boundary of McKay Township showing subhorizontal gneissic layering in highly strained quartz monzonite of the Algonquin Batholith accentuated by their biotite-rich layers (dark grey zones locally defining open folds).

asediments. Cross-cutting relationships of the various phases suggest that the mafic rocks are the oldest followed in order by the monzonitic and syenitic rocks and quartz monzonite.

The intensely strained nature of the batholith rocks can be attributed to diapirism during the Late Precambrian high rank regional metamorphism (Schwerdtner and Lumbers 1980). As shown on the accompanying maps (back pocket), numerous oval diapiric structures are outlined by subhorizontal flattening gneissosity and by lithology. An excellent example is in northern Guthrie Township where an oval structure cored by quartz monzonite is surrounded by monzonitic rocks. The core rocks dip subhorizontally, but have superimposed open folds producing dips up to 35 degrees. These folds are ubiquitous throughout the map-area and appear to represent open folding and warping during uplift following culmination of the high-rank regional metamorphism. This origin for the folds is also supported by the facts that the emplacement of many late pegmatite dikes (map-unit 27) was structurally controlled by the open folds, and structural surfaces related to the folds show slickensides and late cataclasis. All the batholith rocks in areas of subhorizontal gneissosity are markedly strained and show a prominent gneissic layering. In the monzonitic rocks, the layering is commonly reflected by numerous rusty schist zones up to a few metres thick containing graphite and minor amounts of pyrite and pyrrhotite scattered in a sericitic and chloritic quartzofeldspathic matrix. The rusty zones grade into augen gneiss recognizeable as highly strained monzonitic rocks. In quartz monzonite and the mafic rocks, the layering is mainly reflected by biotite-rich zones, generally less than 1 m thick (Photo 1), and rusty schist layers are rare to absent.

Late pegmatite dikes (map-unit 27) are common throughout the batholith, but the largest dikes are present in the mafic phases, and some of these dikes have been exploited for feldspar and mica. Traces of uranium-bearing minerals are common in the pegmatites, but none appear to be sufficiently rich in uranium to be of economic interest.

Metasediments[1]

CLASTIC SILICEOUS METASEDIMENTS

The Late Precambrian supracrustal accumulation is dominated by carbonate metasediments and rests unconformably upon rocks of the Algonquin Batholith. The base of the accumulation consists of a **coarse clastic sequence** characterized by a basal arkose and impure sandstone facies locally containing coarse clasts lithologically similar to intrusive phases of the batholith. The upper part of the coarse clastic sequence grades into the carbonate facies by a progressive increase in the amount of intercalated units, derived from calcareous and siliceous mudstones and siliceous limestone.

[1]The metasediments are subdivided lithologically and the order of subdivisions does not imply age relationships.

Typical exposures of the main lithologies found in the sequence are shown in Photos 2 to 5. From Pembroke southwest to northern Brudenell Township, the underlying batholith is composed mainly of quartz monzonite, and the clastic sequence is dominated by medium- to coarse-grained gneissic arkose and subarkose locally containing intercalated thin units of siliceous marble and gneiss and schist derived from impure sandstone and calcareous and siliceous mudstone (Photos 2 and 3). Coarse clasts are rare to absent. Southwest from northern Brudenell Township, the underlying batholith is rich in tonalite, and the lowest part of the calstic sequence contains several, thin, lensoid units of gneissic arkosic conglomerate rich in tonalite clasts (Photo 4). Most of the sequence here is dominated by micaceous arkosic sandstone containing isolated coarse clasts of gneissic granitic rocks and local units of gneiss derived from medium- to coarse-grained arkose and subarkose and calcareous and siliceous mudstone (Photo 5). Petrographically, variations in plagioclase and potassic feldspar in the arkose and subarkose seem to reflect closely the nature of the underlying batholith rocks; potassic feldspar greatly predominates over plagioclase where quartz monzonite dominates the underlying rocks, and the reverse is so where tonalitic rocks are dominant in the underlying rocks. Evidently, the sequence reflects detritus derived from the underlying batholith and is largely a residue resulting from the reworking of an arkosic regolith. Further work in progress will help to confirm these preliminary conclusions.

OGS 10 298

Photo 2–Typical exposure of medium-grained gneissic arkose and subarkose containing several intercalated units of gneiss and schist derived from calcareous mudstone (dark grey). Highway 512, about 0.7 km south of the northern boundary of Brudenell Township.

OGS 10 287

Photo 3–Coarse-grained, gneissic arkose rich in quartz and alkalic feldspar and containing thin, dismembered units of schist derived from siliceous mudstone (dark grey). Near the southern end of Echo Lake, Bangor Township.

Outliers of the coarse sequence occur within the batholith up to 50 km northwest of the exposed margin of the batholith suggesting that the batholith was once covered by at least part of the Late Precambrian supracrustal accumulation. Metamorphism obscured or destroyed most primary sedimentary structures in the sequence severely limiting analysis of the environment of deposition. Recumbent folding of the sequence due to diapirism of the batholith is responsible for irregular boundaries between the batholith and the sequence, and the presence of inliers of batholith rocks within the sequence. In fact, the contact shown on the maps (Maps 2459, 2460, 2461, back pocket) is greatly generalized and in detail, is considerably more irregular than shown.

Further work, including additional mapping of its eastward and westward continuation, could prove the coarse clastic sequence to be of economic importance because it appears to represent one major environment in which concentrations of uranium are known to form. No such concentrations were found in the sequence during the present study, and the amount of uranium concentrated in the underlying batholith is unknown.

A few sequences composed mainly of metamorphosed arkose and subarkose (map-unit 7) were mapped in various parts of the area, commonly in association with amphibole-rich metasediments and calcareous and shaly metasediments. Locally, the sequences contain intercalated impure metasandstone, siliceous marble, and rarely, orthoquartzite. One of the thickest and most persistent of

OGS 10 288

Photo 4–Gneissic arkosic conglomerate containing coarse clasts of gneissic tonalite (dark grey). East shore of Diamond Lake, Radcliffe Township.

these sequences is in central Lyndoch Township. This sequence also contains locally abundant, coarse-grained arkose similar to that found in the coarse clastic sequence, and abundant intercalated amphibole-rich metasediments and rocks derived from siliceous mudstone. The subarkose in the sequence is mainly a quartzofeldspathic rock dominated by quartz (up to 70 percent) and the feldspar is either predominantly plagioclase or potassic feldspar; most contains less than 10 percent amphibole, biotite, and muscovite. Some subarkose is relatively rich in biotite and muscovite, with coarse porphyroblasts of garnet.

Thinly bedded, biotitic sandstone and biotite-rich shaly metasediments form several thin to relatively thick units in Ross and Horton Townships near Ottawa River, in Admaston and eastern Grattan Townships, and extending southward from Calabogie Lake in Blithfield, North Canonto, and Bagot Townships. These rocks appear to represent thinly bedded greywacke sequences, similar to greywacke sequences interpreted as volcaniclastic aprons deposited about eroded volcanic highlands in the Bancroft-Madoc area (Lumbers 1967; 1969). Most, but not all, of the units in the map-area show some spatial association with metavolcanics in the map-area and to the south, so that these units may also represent apron deposits. Lithologically, the rocks consist mainly of biotite, quartz and oligoclase. Amphibole is locally abundant in some of the rocks and absent in others; potassic feldspar is either absent, or rare, in marked contrast with most of the other clastic siliceous metasediments in the map-

OGS 10 289

Photo 5–Micaceous arkosic sandstone containing a coarse clast of gnaissic quartz monzonite (beneath hammer) and thin intercalated units of schist derived from siliceous mudstone (dark grey). Highway 515, Radcliffe Township about 0.8 km north of Jewellville.

area. Scarcity of potassic feldspar is also characteristic of the volcaniclastic apron deposits. Common accessory constituents are pyrite, pyrrhotite, iron-titanium oxide minerals, allanite, garnet, apatite, titanite, zircon, epidote, tourmaline, and carbonate. A few rocks rich in amphibole also contain scapolite and diopside, and garnet is most abundant in biotite-rich shaly portions. Sequences of these rocks in North Canonto and Blithfield Townships and locally in Admaston and eastern Grattan Townships were intruded by a variety of igneous rocks and contain dikes and sills of these rocks in addition to porphyroblasts of alkalic feldspar and irregularly developed lenses of quartzo feldspathic material. Such rocks are designated by a separate code (6b) on the accompanying maps (back pocket).

On the eastern shore of Mile Lake in southern Blithfield Township, silty, biotitic units less than 1 m thick and intercalated with greywacke contain a few layers generally less than 1 cm thick rich in magnetite. This rock probably is derived from iron formation.

One occurrence of intraformational conglomerate was mapped on an island in Black Donald Lake near the eastern boundary of Matawatchan Township. This rock contains a variety of clastic siliceous metasedimentary clasts and coarsely recrystallized quartz clasts in a biotite-rich matrix containing sillimanite, quartz, plagioclase, and garnet.

Carbonate metasediments (map-unit 10) consist of marbles derived from impure limestone and dolostone. Most of the marble is calcite-rich and contains at least 5 percent siliceous impurities. Two main varieties of calcite-rich marble are distinguished on the maps (back pocket): 1) calcitic marble containing less than 20 percent siliceous impurities; and 2) siliceous marble containing 20 to 60 percent siliceous impurities. Both varieties contain the following impurities: phlogopite, chlorite, pyrite, pyrrhotite, graphite, quartz, apatite, titanite, tremolite, potassic feldspar, plagioclase, brown tourmaline and zircon. The siliceous variety also contains scapolite, diopside, epidote, allanite, and biotite. Most commonly, the two varieties are intercalated, and variations in the amount of impurities reflect original bedding. Thin units of amphibole-rich metasediments and minor calcareous and siliceous shaly metasediments are commonly intercalated with siliceous marble and also serve to indicate original bedding. Some calcitic marble contains up to 5 percent very fine-grained pyrite, and when struck by a hammer, it gives a strong odour of H_2S. Such marble contains minor intercalated dolomitic marble and is most common near Ottawa River in Ross and Horton Townships. Rarely, units up to several metres thick of orthoquartzite and subarkose are intercalated with calcitic marble. Most of the marble is coarsely recrystallized and grey to light grey with average grain sizes ranging between 2 and 5 mm. Locally in highly strained zones in marble-rich terrains containing recumbent folds and subhorizontal gneissosity such as north of Leclaire Lake in Matawatchan and Brougham Townships, very coarse calcitic marble with average grain sizes up to 1 cm predominate. In the marble-rich terrain of McNab Township where gneissic foliation dips subvertically, the marbles are locally distinctly less strained and recrystallized than elsewhere. Fine-grained, dark grey calcitic and siliceous marbles intercalated with coarser marbles show well-preserved bedding features. They contain abundant very fine-grained graphite which causes the dark grey colour, and diopside, scapolite, epidote, and allanite are rare to absent.

Most of the dolomitic marble occurs southeast of the major alkalic complex, and except for minor unmappable thin units in calcitic marble and moderately thin units near Centennial and Black Donald Lakes in Matawatchan, Brougham, and North Canonto Townships, all major units of dolomitic marble show some spatial association with metavolcanics. Such an association has also been recognized elsewhere within the Late Precambrian supracrustal accumulation (Lumbers 1964, 1969). Two main varieties of dolomitic marble are present: 1) medium to coarse-grained, white to greenish dolomitic marble relatively free of impurities; and 2) medium to coarse-grained cherty dolomitic marble containing numerous thin beds of coarsely recrystallized chert and siliceous zones rich in tremolite. The main impurities in both varieties are phlogopite, chondrodite (commonly partly to completely serpentinized), quartz, chlorite, graphite, tremolite, apatite, diopside, talc, scapolite, titanite, pyrite, and pyrrhotite. Cataclastic deformation of tremolite-rich dolomitic marble along fault zones produced fibrous tremolite, a form of asbestos. Southwest of Renfrew in Admaston Township, a thick unit of dolomitic marble and cherty dolomitic marble locally contains concentrations of sphalerite accompanied by minor pyrite and rare galena confined to relict beds indicating that this mineralization formed either

during, or shortly after, deposition of the marble. The relatively thick dolomitic marble unit in southern Ross Township contains several zones with only minor impurities, and some of these are quarried for building stone, and the production of magnesium.

Skarn, a light to dark green, medium- to coarse-grained rock rich in diopside and amphibole, is commonly developed in the carbonate metasediments near contacts with intrusive rocks and in the vicinity of late pegmatite dikes. This rock is particularly abundant in the alkalic complex which contains numerous arcuate screens and xenoliths of carbonate metasediments. Most of the skarns are massive to only slightly gneissic, but some have undergone extreme deformation and recrystallization. In addition to diopside and amphibole, the other major minerals present are scapolite, carbonate, titanite, and potassic feldspar. Minor minerals, some of which are major constituents in a few skarns, are pyrite, pyrrhotite, chalcopyrite, molybdenite, magnetite, vesuvianite, fluorite, phlogopite, plagioclase, zircon, biotite, epidote, chlorite, apatite, garnet, magnetite and allanite. A few skarns are radioactive and possibly contain uranium minerals. The distribution, mineralogy and field relationships of the skarns suggest that most were formed by the reaction of carbonate metasediments with either fluids rich in Si, Al, Fe and Mg derived from adjacent intrusive rocks, or fl ds responsible for pegmatite dike formation.

In Bagot Township north of Calabogie Lake on the abandoned railway line, an exposure of siliceous marble contains a few thin units of feldspar-quartz-scapolite-carbonate gneiss containing layers rich in pyrite and pyrrhotite. This rock could have been derived from sulphide facies iron formation. Similar rocks also occur near the northern end of Centennial Lake in Matawatchan Township.

Other calcareous metasediments in the map-area are derived from either calcareous and siliceous mudstones containing minor sandy and carbonate sediments, or from clay-rich to quartz-rich sandstones. Mappable units of rocks derived from calcareous mudstone are intercalated with the carbonate metasediments and are associated with units of clastic siliceous metasediments. Calcareous mudstone represents facies changes from predominantly chemical and biochemical sedimentation to clastic sedimentation. Thus, original carbonate and siliceous components in this rock varied considerably, and upon metamorphism, this variation produced a variety of petrographic types. These rocks show prominent lithologic layering due to large variations in mineralogy, but in general, they contain abundant amphibole and plagioclase and are referred to herein as amphibole-rich metasediments (map-unit 9). In addition to amphibole and plagioclase, individual layers contain accessory to essential amounts of diopside, potassic feldspar, biotite, scapolite, epidote, carbonate, titanite, apatite, zircon, garnet, tourmaline, pyrite, pyrrhotite, and iron-titanium oxide minerals. The mineralogical layering reflects original bedding, and other types of metasediments are intercalated with these rocks as subordinate thin units paralleling the layering. In amphibole-rich metasedimentary units within carbonate metasediment sequences, the subordinate units are commonly siliceous marble. Where amphibole-rich metasediments are associated with thicker sequences of clastic siliceous metasediments, the subordinate units are dominated by clastic siliceous metasediments. Near Calabogie Lake in Bagot Township, amphibole-rich metasediments intercalated with rocks derived mainly

from siliceous mudstones (map-unit 8) locally contain thin, coarsely recrystallized cherty layers and layers up to a few centimetres thick rich in iron-titanium oxide minerals and pyrite. These ferruginous rocks were probably derived from iron formation.

Rocks derived from siliceous mudstone differ from the amphibole-rich metasediments in containing minor or no amphibole, generally abundant quartz, plagioclase, and biotite, and coarse porphyroblasts of garnet. They also vary considerable in mineralogy and in addition to the aforementioned minerals, they contain accessory to essential amounts of potassic feldspar, muscovite, sillimanite, scapolite, diopside, carbonate and iron-titanium oxide minerals; titanite, apatite, graphite, pyrite, pyrrhotite, tourmaline, chlorite, allanite and zircon are the main accessory minerals. Diopside, scapolite, and carbonate are present only in rocks containing amphibole; sillimanite is confined to quartz-rich phases lacking calc-silicate minerals. One occurrence of siliceous mudstone intercalated with greywacke on the west shore of Ottawa River, about 2.5 km west of Muskrat Rapids in Ross Township, contains minor cordierite. The siliceous mudstone occurs in thinly bedded sequences containing subordinate amounts of intercalated quartzose and feldspathic sandstones, amphibole-rich metasediments, and siliceous marble (Photo 6), and they form subordinate layers in sequences of amphibole-rich metasediments and rocks of units 6a and 6b. Sequences composed mainly of siliceous mudstone are designated as map-unit

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Photo 6–Thinly bedded sequence of metasediments derived from siliceous mudstone (grey) and quartzose and feldspathic sandstone (light grey) with an intercalated unit of amphibole-rich metasediments (dark grey) to the right of the hammer handle. Brougham Township, 5 km north of the north end of Norcan Lake.

8 on the accompanying maps (back pocket), and are included under the calcareous metasediments because of a high content of amphibole-rich metasediments and locally abundant siliceous marble.

Metavolcanics

Rocks most likely derived from metavolcanics are scarce in the map-area and are confined to the following: 1) predominantly felsic to intermediate metavolcanics of the Oak Lake formation (Lumbers 1967) near the southwestern corner of the area in Raglan, Mayo and Ashby Townships; 2) mafic metavolcanics in northern Denbigh Township; 3) two thin units of felsic to intermediate, and mafic metavolcanics in the dolomitic marble sequence containing zinc mineralization southwest of Renfrew in Admaston and Bagot Townships; 4) predominantly mafic metavolcanics near Ottawa River in Ross Township; and 5) mafic metavolcanics near the southern shore of White Lake and the southern end of the White Lake trondhjemite in Bagot and Darling Townships. This last unit is part of an extensive sequence of metavolcanics trending southwestward beyond the map-area (see Figure 2). The metavolcanics are highly deformed and recrystallized, so that only vestiges of primary volcanic structures are preserved. The mafic metavolcanics are amphibolite, rich in plagioclase, amphibole, iron-titanium oxide minerals, and titanite. Relic pillows and stretched plagioclase phenocrysts and amygdaloidal structures are the main primary

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Photo 7–Micaceous, fragmental, quartzofeldspathic schist possibly derived from pyroclastic deposits; the light grey, highly stretched fragments are composed mainly of fine-grained quartz and feldspar. Admaston Township, 3 km southwest of Renfrew.

volcanic structures preserved. Felsic and intermediate metavolcanics consist mainly of fine-grained, leucocratic, quartzofeldspathic gneiss and schist and micaceous quartzofeldspathic schist. Micaceous varieties commonly contain both biotite and muscovite and minor garnet and amphibole; sillimanite occurs rarely. Many of the units contain abundant potassic feldspar, but in some, sodic oligoclase is the dominant feldspar. Fragmental facies are present in felsic units in Admaston Township (Photo 7) and at the southwestern boundary of the map-area. This facies and the micaceous facies may represent pyroclastic deposits. The leucocratic quartzofeldspathic facies may represent original felsic flows, but relic primary structures indicative of this origin were not found in these rocks.

East of Calabogie Lake in Bagot Township and in northern Denbigh and southern Lyndoch Townships, units of amphibolite and quartz amphibole-plagioclase gneiss may, in part, be derived from mafic metavolcanics. The Bagot Township unit contains abundant intercalated siliceous marble and impure metasandstone units generally less than 2 m thick, whereas the other unit consists mainly of prominently layered amphibolite with layering reflected by variations in amphibole, quartz, and plagioclase contents. No unequivocal primary volcanic structures were found in either unit, and on the accompanying maps (Maps 2461, 2462, back pocket) the rocks are designated by a separate code (map-unit 9e) under amphibole-rich metasediments. Highly strained and recrystallized phases of gabbro and diorite bodies are similar in appearance to the unit in Lyndoch and Denbigh Townships, and this unit is at the margin of such a mafic intrusive body. Recognizeable mafic metavolcanics were also mapped near this unit in northern Denbigh Township.

Rusty Schist

Rusty weathering, graphitic schist is widespread throughout the Late Precambrian supracrustal rocks and is particularly common at contacts between carbonate metasediments and both more siliceous metasediments and plutonic rocks. Such contacts containing rusty schist show evidence of late shearing. The schist also occurs as isolated pods up to a few metres long in siliceous marble and in shear zones near major faults. Only a few units are sufficiently large to be shown on the accompanying maps (back pocket). The schist is similar lithologically to rusty schist developed in the Algonquin Batholith and mapped in the Bancroft-Madoc area southwest of the map-area (Lumbers 1967). Locally, the schist is rich in pyrite and pyrrhotite, and one unit in southeastern Blithfield Township was mined for pyrite (No. 10, on Map 2462). Many occurrences of the schist show evidence of a replacement origin at a late stage during the high rank regional metamorphism. Much of the schist is developed in irregular zones that cut across 1) bedding and gneissosity in the metasediments, and 2) lithologic layering and gneissosity both at the margins and within the interior of metamorphosed intrusive bodies. Much of the rusty schist in the Bancroft-Madoc area also shows evidence of a replacement origin, but some also appears to be derived from pyritic black shale (Lumbers 1967; 1968; 1969). Further work is necessary before these rocks can be satisfactorily interpreted.

TABLE 1 — MODAL CLASSIFICATION OF NON-FELDSPATHOIDAL PLUTONIC ROCKS

QUARTZ	ESSENTIAL FELDSPAR					MONOMINERALIC	< 10% FELDSPAR
	Potassic Feldspar / Total Feldspar	Composition of Plagioclase: Albite An_{0-10}	Oligoclase An_{10-30}	Andesine An_{30-50}	Labradorite and Bytownite An_{50-90}		
> 10%	> 2/3	Alkalic Granite	Quartz Monzonite				
	1/3 – 2/3						
	1/8 – 1/3	Sodic Granite	Granodiorite				
	< 1/8	Albite Granite	Trondhjemite	Tonalite	Quartz Gabbro		
< 10%	> 2/3	Alkalic Syenite	Calc-alkalic Syenite			Anorthosite	Peridotite
	1/3 – 2/3		Monzonite			Hornblendite	
	1/8 – 1/3	Sodic Syenite	Syenodiorite			Pyroxenite	
	< 1/8	Albite Syenite	Oligoclase Diorite	Diorite	Gabbro	Dunite	

Notes: a) Common varieties of gabbro and anorthosite are:

1. Norite: a gabbro with more orthopyroxene than clinopyroxene
2. Anorthositic gabbro: a gabbro with 22.5% to 35% ferromagnesian minerals
3. Gabbroic anorthosite: an anorthosite with 10% to 22.5% ferromagnesian minerals
4. Plagioclase content of anorthosite ranges between oligoclase and anorthite

b) Quartz content of tonalite is rarely > 20%, and of quartz gabbro, rarely > 10%

c) Granites, quartz monzonite, granodiorite, and trondhjemite generally contain > 20% quartz

d) Quartz syenite refers to syenite containing between 10 and 20% quartz

Biotite Diorite Suite Intrusive Rocks

Rocks of the biotite diorite suite can be subdivided into three main groups (map-units 13, 14 and 15): 1) diorite and related mafic rocks; 2) syenitic rocks; and 3) granitic rocks. The main rock types comprising each group are classified according to the scheme shown in Table 1. This classification scheme differs from many of the current plutonic rock schemes based upon mineral content, chiefly in a more detailed subdivision of the syenitic and granitic rocks. Such a subdivision is necessary in order to distinguish among the common rock-types found in the various plutonic suites and to relate these rocks to mineral deposits. Many current schemes do not distinguish granodiorite, trondhjemite, and tonalite, three of the most abundant rocks of the biotite diorite suite. Although the classification used here may prove useful in a more general context, it is designed specifically to facilitate discussion of the various members of the plutonic rock suites present in the map-area.

Rocks of the biotite diorite suite form several sill-like bodies, stocks, and small batholiths throughout the southeastern part of the area, south and east of the large complex of alkalic suite intrusive rocks. Most of the intrusions are dominated by either diorite, or trondhjemite, but a few, such as the Slate Falls complex, are rich in both mafic and granitic phases. Rocks of the syenite group are mainly confined to the Norway Lake complex in Bagot Township, the stock in Admaston and Horton Townships north of the Hurds Lake trondhjemite, and the dioritic stocks south of Calabogie Lake in Bagot and Blithfield Townships and west of Colton Lake in Admaston Township.

All the intrusions of the suite are regionally metamorphosed, but the level of strain and recrystallization of the rocks varies greatly. In general, the most highly strained and recrystallized rocks coincide with areas where gneissic foliation dips less than 60 degrees. The Norway Lake complex , which for the most part displays subhorizontal gneissosity is perhaps the most highly strained and recrystallized intrusion. Moderately strained and recrystallized portions of the intrusions are characterized by augen structure, and relict primary igneous textures are commonly preserved. Zones of high strain are characterized by prominent gneissic layering, and primary igneous textures are largely destroyed.

Mafic rocks of the suite are dominated by diorite and tonalite. Where least deformed, diorite consists mainly of plagioclase and amphibole (in part, altered pyroxene), whereas tonalite contains visible quartz and biotite in addition to plagioclase and amphibole. Both rocks generally contain at least 30 percent mafic minerals, but relatively leucocratic phases are found containing only 10 to 15 percent mafic minerals. Leucocratic tonalite is difficult to distinguish from trondhjemite in the field; most of the leucotonalite appears to be confined to the Slate Falls complex in southern Lyndoch and northern Denbigh Townships. Minor gabbro containing sodic labradorite (An_{50} to An_{55}) is commonly associated with diorite, but the two rocks cannot be reliably distinguished in the field. Locally in some diorite intrusions, such as the Raglan Hills body, recrystallized pyroxenite and peridotite form small irregularly shaped masses (too small to show on map) that cut across the diorite. Plagioclase in diorite ranges in composition from An_{30} to An_{50}, and in tonalite, from An_{30} to An_{40}. Highly strained phases of both diorite and tonalite commonly contain garnet

porphyroblasts generally less than 5 mm across. One highly strained diorite and gabbro body near the northern end of Lac Du Rocher-Fendu on Ottawa River, Ross Township, contains abundant garnet up to a few centimetres in size. Cordierite, hypersthene, and garnet are present in highly strained tonalite forming part of a trondhjemitic stock near the southern end of Lac Du Rocher-Fendu. Associated trondhjemite contains cordierite and garnet where highly strained. This is the only occurrence of cordierite and hypersthene observed in rocks of the biotite diorite suite, and the only occurrence of the assemblage garnet-cordierite-hypersthene found in the map-area. Such an assemblage is commonly regarded as indicative of granulite facies metamorphism (Winkler 1976).

Syenitic rocks consist mainly of gneissic, leucocratic albite syenite in which quartz is lacking or rare. Locally, the quartz content increases to form albite-quartz syenite and albite granite. Potassic feldspar is rare or lacking in all these rocks. Some of the rocks containing quartz also contain minor pyroxene intergrown with amphibole, and this aggregate forms peculiar arcuate wisps prominent on weathered surfaces. The stock containing syenitic rocks just north of the Hurds Lake trondhjemite in Admaston and Horton Townships is lithologically extremely complex with heterogeneous mixtures of albite syenite and sodic granitic rocks rich in screens and xenoliths of metasediments. Near the southeastern part, the stock is relatively homogeneous and consists mainly of trondhjemite, granodiorite, and sodic quartz syenite. Tourmaline is a common accessory mineral in most of the rocks, and this is the only intrusion of biotite diorite suite rocks in which accessory tourmaline was identified. Further work is required to satisfactorily interpret the intrusion, and on the accompanying map (Map 2462, back pocket), the complex rock assemblage is designated by map-unit 14b. One possible explanation for the heterogeneous lithology is that the present erosion surface intersects the roof zone of the intrusion exposing contaminated intrusive phases formed by the reaction of the magma with the enclosing metasediments.

Granitic rocks of the suite consist of trondhjemite, granodiorite, and minor albite granite and quartz monzonite. Potassic feldspar forms less than 5 percent of the trondhjemite which is generally a grey to pink, medium-grained to rarely coarse-grained rock generally containing no more than 15 percent biotite, amphibole and epidote as the main mafic constituents. Trondhjemite locally grades into leucotonalite described above, and near contacts with marble, trondhjemite containing up to 30 percent amphibole is developed, commonly with numerous skarn and calc-silicate xenoliths. This mafic trondhjemite closely resembles tonalite in hand specimen. The amphibole content of trondhjemite crudely reflects the composition of plagioclase. Trondhjemite, in which the plagioclase composition is between An_{10} and An_{20}, contains little or no amphibole and is not associated with leucotonalite. Trondhjemite in which the plagioclase composition is between An_{20} and An_{30} commonly contains amphibole as the main mafic constituent, and such trondhjemite locally grades into leucotonalite by a slight increase in the anorthite content of plagioclase. Quartz generally forms between 20 and 35 percent of the trondhjemite. Granodiorite is similar to trondhjemite, except for a higher content of potassic feldspar. Some granodiorite is markedly porphyritic with relict plagioclase and potassic feldspar crystals up to a few centimetres in size. Such rocks are best

developed in the Griffith batholith. Albite granite and quartz monzonite generally form late dikes in trondhjemite and granodiorite, but in some intrusions in Matawatchan Township major phases of intermixed granodiorite and quartz monzonite are present. Gneissic granite pegmatite dikes are common in some intrusions rich in granitic rocks, and the dikes were most likely formed at a late stage during the emplacement of the intrusions.

Most of the mineralization associated with the biotite diorite suite occurs in dioritic intrusions. Minor copper and nickel are concentrated in mafic gabbro or pyroxenite and peridotite, and small contact metasomatic iron deposits are present in marble bordering some dioritic intrusions containing syenitic phases. Concentrations of molybdenite occur in metasomatized carbonate metasediments occurring in screens or at the borders of some trondhjemite-rich intrusions.

Mafic Sills and Dikes

Small dikes and sills of amphibolite derived from gabbro are common in the metasediments and many of the intrusive rocks throughout the map-area. Most of these mafic bodies are too small to be shown on the accompanying maps (back pocket), but they are particularly common in marble-rich portions of the Late Precambrian supracrustal accumulation where they form relatively large bodies in Horton, McNab, Ross, and Lyndoch Townships. The age of the intrusions is unknown, except that they predate the late high rank regional metamorphism. They most likely represent multiple ages. Some of the intrusions in the Late Precambrian supracrustal rocks could be related to volcanism, whereas others in the Algonquin Batholith and Middle Precambrian metasediments could be older than the deposition of the Late Precambrian supracrustal rocks.

Anorthosite Suite Intrusive Rocks

Anorthosite suite intrusive rocks that intruded the Late Precambrian supracrustal rocks can be subdivided into two main groups: 1) anorthosite and related mafic rocks (map-unit 17); and 2) monzonitic and syenitic rocks (map-unit 18). Granitic phases are rare in marked contrast to anorthosite suite rocks forming the Algonquin Batholith. Most of the anorthosite suite rocks are associated spatially with the large alkalic complex, and although they are scattered throughout the complex, they are most abundant in that part lying east of Brudenell Township. Four small bodies of these rocks occur southeast of the complex, one trending southwestward from Colton Lake in Admaston Township, another, the Elbow anorthosite, that straddles Madawaska River in Blithfield Township, a third at the southern end of Norcan Lake, North Canonto Township, and a fourth, the Burns Lake complex, in northeastern Griffith Township.

Lithologically, the anorthosite suite rocks are similar to those of the Algon-

quin Batholith and others mapped elsewhere in the Grenville Province of Ontario (Lumbers 1971; 1975; 1976a; 1976b; Lumbers and Krogh 1977). The rocks are strained and recrystallized due to superimposed high rank regional metamorphism, and the most highly metamorphosed phases coincide with zones of shallow dipping to subhorizontal gneissosity. Where least metamorphosed, the rocks are augen gneisses displaying relict primary igneous textures. Gneissic phases showing prominent mineralogical layering and little or no relict primary igneous textures are confined to areas of subhorizontal to shallowly dipping gneissosity.

Most of the anorthositic rocks contain oligoclase or andesine and about 10 to 25 percent ferromagnesian minerals, and dioritic phases, containing up to 45 percent ferromagnesian minerals, are commonly associated with the anorthositic rocks. Labradorite-bearing anorthosite is confined mainly to the Elbow anorthosite in Blithfield Township and is associated with minor gabbroic anorthosite and locally abundant tonalite which is concentrated mainly near the margins of the body. Plagioclase in the anorthositic phases in Blithfield Township ranges in composition from about An_{55} to An_{70}. Ferromagnesian constituents in all the anorthositic rocks are mainly amphibole and biotite, but a few contain minor clinopyroxene and epidote. Many of the oligoclase and andesine anorthosites contain a trace to about 2 percent potassic feldspar, and all the anorthositic rocks contain scapolite and less than 1 percent quartz intergrown with amphibole and biotite. Corundum-bearing andesine anorthosite, containing less than 10 percent biotite as the only ferromagnesian mineral, is confined to the alkalic complex as xenoliths in alkalic syenite. Gneissic tonalite is common in the alkalic complex where it forms relatively large bodies intruded by alkalic granite-rich portions of the complex. Most of the tonalite is similar to tonalite of the Algonquin Batholith and the biotite diorite suite, but a garnet-rich variety occurs sparingly in the alkalic complex and is best developed in central Grattan Township. This rock is essentially garnet-biotite-quartz-andesine gneiss with quartz constituting 15 to 20 percent of the rock, and garnet 8 to 15 percent.

Monzonitic and syenitic rocks are associated mainly with anorthositic rocks south of Mink Lake in Wilberforce Township and east and north of Muskrat Lake in Westmeath Township. The intrusion trending southwest from Colton Lake in Admaston Township and the Burns Lake complex, are rich in monzonitic and syenitic rocks. The Colton Lake intrusion contains minor late phases of alkalic syenite.

The age of the anorthosite suite rocks cutting the Late Precambrian supracrustal rocks is poorly known. Field relationships indicate that they are older than alkalic syenite and granite of the alkalic suite, and two bodies are cut by rocks of the quartz monzonite suite. No rocks of the anorthosite suite are in contact with rocks of the biotite diorite suite, so that relative age relationships between these two suites cannot be established in the field. The abundance of anorthosite suite rocks in the alkalic complex may be fortuitous, but elsewhere in the Grenville Province of Ontario alkalic rocks are also closely associated with anorthosite suite rocks suggesting that a genetic link may exist between the two suites (Lumbers 1975; 1976b).

Quartz Monzonite Suite Intrusive Rocks

The quartz monzonite suite is mainly expressed as a series of intrusions extending northward from North Canonto Township to Horton Township. Other intrusions of the suite are present in southeastern Lyndoch Township and at the southwestern corner of the map-area in Mayo and Ashby Townships. Most intrusions of the suite are regionally metamorphosed and gneissic, but a few are only slightly metamorphosed and are predominantly massive, suggesting that they were emplaced during the waning stages of the regional metamorphism. The massive intrusions are confined to Brougham Township in the vicinity of the Mount St. Patrick syenite, and to the McArthurs Mills pluton in Mayo and Ashby Townships at the southwest corner of the map-area. The McArthurs Mills pluton has been dated isotopically (U-Pb in zircon) at about 1.06 Ga old (Silver and Lumbers 1966).

Lithologically, the suite consists mainly of leucocratic quartz monzonite, but phases containing up to 20 percent ferromagnesian minerals are locally common. Plagioclase ranges in composition from about An_{10} to An_{25}, but in some intrusions composed mainly of leucocratic quartz monzonite, plagioclase is slightly more sodic than An_{10} producing alkalic granite. Potassic feldspar varies in abundance within some intrusions, so that locally, granodiorite is present. Muscovite, biotite, and amphibole are the only other abundant minerals in rocks of the suite. Titanite, epidote, apatite, iron-titanium oxide minerals, allanite, and zircon are the main accessory constituents. Amphibole is most abundant in granodiorite phases and in quartz monzonite containing skarn or amphibolite xenoliths. Otherwise, biotite and muscovite either greatly predominate over amphibole, or amphibole is absent.

The large area of quartz monzonite suite rocks in North Canonto and Blithfield Townships cuts anorthosite suite rocks, and lithologically, the quartz monzonite contains abundant xenoliths of amphibolite and tonalitic rocks, much the same as quartz monzonite of the Algonquin Batholith. Perhaps further work may provide data to genetically connect some of the quartz monzonite suite intrusions with the anorthosite suite. Massive to only slightly gneissic quartz monzonite near the Mount St. Patrick syenite could be related to the syenite, but further work is also needed to prove such a relationship.

Alkalic Suite Intrusive Rocks

The alkalic suite is the most variable of the various plutonic rock suites recognized. Lithologically, rocks of the suite can be subdivided into four major groups: 1) alkalic granite; 2) alkalic syenite; 3) nepheline syenite; and 4) mafic alkalic rocks. Except for nepheline syenite pegmatite formed during the latter stages of the late high rank regional metamorphism, rocks of the nepheline syenite group were completely recrystallized and highly deformed during this metamorphism. Some rocks of the other three groups were only slightly recrystallized and deformed during the regional metamorphism, whereas others are completely recrystallized gneisses. Thus, the suite was apparently emplaced over an interval encompassing the waning stages of the regional metamor-

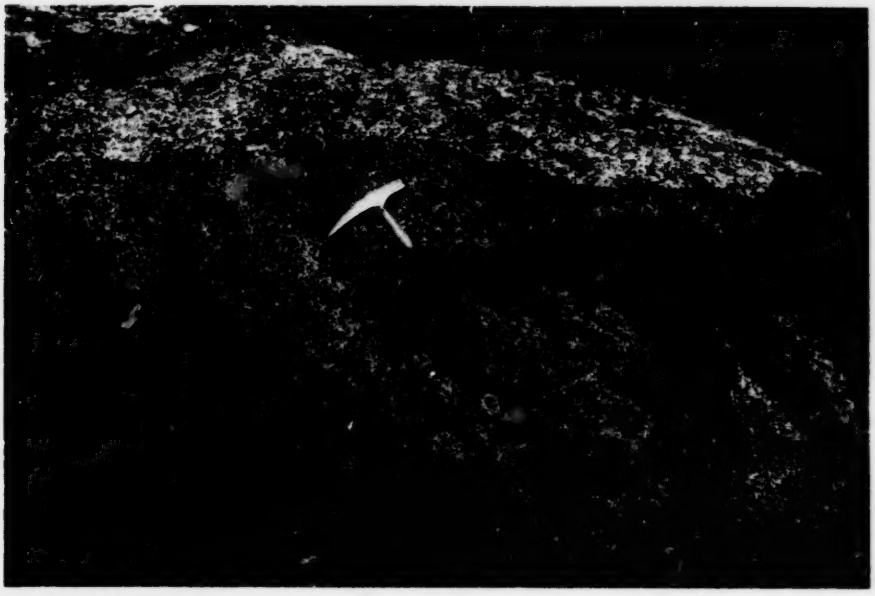
phism. Rocks of the suite are concentrated mainly in one major complex lying just south of the Algonquin Batholith. Minor occurrences of the suite also occur south of the main complex in southern Raglan and Lyndoch Townships and near Calabogie Lake in Bagot Township. Portions of the alkalic complex have been studied over the years, and most of the studies have concentrated upon associated corundum mineralization and the distribution and petrogenesis of the nepheline syenites (see, for example, Hewitt 1961; Carlson 1957; Appleyard 1967). Until the present study, the existence and rock associations of the alkalic complex remained largely unknown. Only a few of the major features of the complex will be summarized here; more detailed accounts will be given following completion of studies in progress.

Mafic rocks of the suite consist of alkalic gabbro and diorite, ijolite, mafic scapolite-bearing gneisses of complicated mineralogy possibly derived in part from ijolitic rocks, and magnetite-rich rocks. Both massive and gneissic phases of the gabbroic and dioritic rocks are present. Massive phases containing primary igneous textures and mineralogy are found only locally within gabbroic and dioritic bodies and consist mainly of 40 to 85 percent biotite, clinopyroxene (partly altered to amphibole), and olivine, and 15 to 60 percent sodic plagioclase ranging in composition from about An_{15} to An_{45}. Some of these rocks also contain minor potassic feldspar. Olivine is confined to mafic-rich, melanocratic phases which also contain the most calcic plagioclase. Metamorphosed phases of the gabbroic and dioritic rocks consist mainly of plagioclase (sodic oligoclase to andesine), 25 to 50 percent amphibole, clinopyroxene, and biotite, and generally abundant titanite and apatite; minor potassic feldspar is present in some of these rocks and absent in others. In the field, these rocks are similar in appearance to gabbro present in some of the other plutonic rock suites. The mafic alkalic body east of Calabogie Lake in Bagot Township is one of the largest of the alkalic gabbro and diorite bodies, and like many of these bodies, it is cut by a few alkalic syenite dikes. Such dikes, if present, are the best clue in the field to suggest the alkalic nature of the mafic rocks. Only one occurrence of massive ijolite was mapped and this is in northwestern Raglan Township on the east side of Little Mississippi River near its junction with York River in Conroys Marsh. The rock is coarse grained and consists mainly of nepheline and dark brown titanaugite which is partly enveloped by a corona of fine-grained garnet and amphibole. Mafic scapolite-bearing gneiss is associated with rocks of the nepheline syenite group and is most abundant in the Wolf nepheline syenite body in Lyndoch Township described by Appleyard (1967). Magnetite-rich rocks occur in the alkalic gabbro body in Bagot Township east of Calabogie Lake, in alkalic granite in Grattan Township east of Highway 41, and sparingly in the Wolf nepheline syenite body (Appleyard 1967). The occurrences in Bagot and Grattan Townships have been mined as iron deposits. The Bagot Township occurrence appears to be a contact metasomatic deposit developed in marble. The Grattan Township occurrence consists mainly of various mixtures of magnetite, titanite, quartz, clinopyroxene, albite, potassic feldspar, biotite, and zircon, and it occurs as a series of lenses in alkalic granite.

Rocks of the nepheline syenite group form only a minor part of the alkalic complex and are found in Sebastopol, Griffith, Brudenell, Lyndoch, and Raglan Townships. Most of these occurrences were mapped previously (Hewitt 1961; Appleyard 1967; Themistocleous 1978, 1979), but one occurrence in Lyndoch

Township at the northeastern margin of the alkalic granite body containing the Jamieson mine (No. 14, Map 2461, back pocket) was not mapped previously. In addition, a few boulders of gneissic nepheline syenite were found in the southwest corner of Lyndoch Township east of the McCoy Mine (No.17, Map 2461, back pocket), but the gneiss was not found in outcrop. The nepheline syenite consists of two main lithologic types: 1) perthitic, biotite nepheline syenite, which is generally leucocratic with muscovite, carbonate, plagioclase, iron-titanium oxide minerals, apatite, and titanite as the main accessory constituents; and 2) plagioclase nepheline syenite which varies greatly in mineralogy and contains various amounts of scapolite, biotite, titanite, iron-titanium oxide minerals, vesuvianite, carbonate, muscovite, corundum, apatite, garnet, amphibole, sodic pyroxene, fluorite, and rarely, minor potassic feldspar. Plagioclase in both varieties ranges in composition from An_0 to An_{25}, the perthitic variety generally contains albite or sodic oligoclase. Nepheline syenite pegmatite is a massive, coarse-grained rock composed mainly of nepheline, sodic plagioclase (commonly albite), and locally, carbonate. It occurs as lenses, both cross-cutting, and subparallel to, the gneissic foliation in the nepheline syenite and as irregularly shaped masses in mafic scapolite-bearing gneiss.

The most common lithology present in the alkalic syenite group consists of massive to gneissic, medium to coarse-grained, sodic pyroxene-albite-perthite syenite (Photo 8) containing variable amounts of amphibole (generally an alteration product of pyroxene), biotite, titanite, apatite, iron-titanium oxide



OGS 10 292

Photo 8–Slightly gneissic sodic pyroxene-albite-perthite syenite relatively rich in sodic pyroxene (dark grey); Sebastopol Township, 2 km southeast of Foymount.

minerals, allanite, zircon, carbonate, and muscovite; trace amounts of garnet, scapolite, tourmaline, graphite, and nepheline are rarely present. One occurrence of this syenite rich in graphite flakes up to 1.5 cm across was mapped just east of Reid Lake near the west-central boundary of Brudenell Township. Optical determinations indicate that the pyroxene is in the soda hedenbergite–aegirine-augite compositional range. Titanite is generally abundant (up to 10 percent) in most of the syenite, and locally, the syenite contains quartz and grades into alkalic granite containing sodic pyroxene. Gneissic syenites containing little or no sodic pyroxene and generally only minor potassic feldspar, are found sparingly as xenoliths in the sodic pyroxene syenite and are particularly common in association with nepheline syenite. These syenites are generally leucocratic and dominated by albite or sodic oligoclase, and various mixtures of biotite, muscovite, amphibole, corundum, titanite, iron-titanium oxide minerals, carbonate, and zircon. Many occurrences of these leucocratic syenites are characterized by heterogeneous mixtures of sodic pyroxene and amphibole syenites, leucocratic syenite pegmatite (locally containing nepheline and corundum), mafic scapolite-bearing gneiss, and gneissic andesine anorthosite. Many of the corundum occurrences are in this type of lithology which is designated as map-unit 22c.

The alkalic granite is mainly a massive to gneissic, pink, leucocratic, medium- to coarse-grained rock composed of albite, quartz, and perthitic potassic

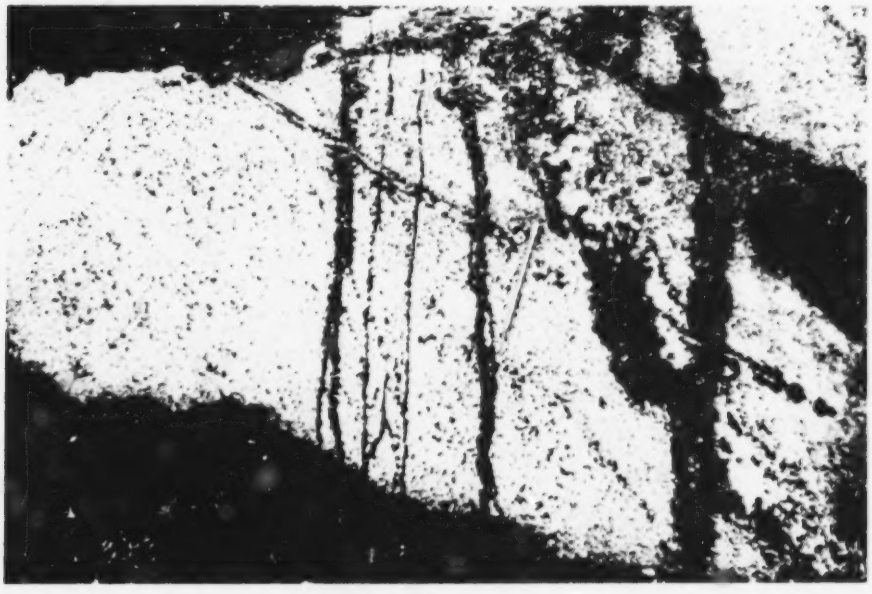


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Photo 9–Gneissic, leucocratic, sodic pyroxene syenite containing late veins of sodic pyroxene; about 5.6 km west-northwest of Haley Station, Ross Township.

feldspar with accessory biotite, sodic clinopyroxene, titanite, apatite, carbonate, iron-titanium oxide minerals, zircon, allanite, amphibole, muscovite, and rarely, fluorite and tourmaline. Iron-titanium oxide minerals (mainly magnetite) are commonly abundant and form as much as 12 percent of the rock. In places, particularly within some major units of sodic pyroxene syenite and near Lake Clear in Sebastopol Township, sodic pyroxene forms 10 to 15 percent of the alkalic granite. Although potassic feldspar greatly predominates over albite in most of the occurrences of the granite, local phases of sodic granite containing more albite than potassic feldspar are not uncommon. Massive varieties, which were only slightly affected by regional metamorphism, contain a few miarolitic cavities containing quartz and feldspar crystals, and, rarely, fluorite.

Throughout most of the alkalic complex, sodic pyroxene alkalic syenite and sodic pyroxene alkalic granite commonly contain numerous patches and intersecting veinlets of coarse-grained sodic pyroxene (mainly soda hedenbergite and aegirine-augite) locally containing intergrown sodic amphibole and coarse-grained apatite and calcite (Photo 9), and dikes and nests of sodic pyroxene syenite pegmatite and granite pegmatite (map-unit 27). Sodic pyroxene syenite and sodic pyroxene alkalic granite rich in the pyroxene veinlets locally contain scattered lenses of apatite-calcite pegmatite (Photo 10) up to several

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Photo 10–Apatite-calcite pegmatite containing coarse crystals of apatite (below hammer) amphibole (dark grey) and alkalic feldspar. Concession road, 3 km south of Cobden and 0.4 km east of Highway 17, Ross Township.

metres long and generally only a few metres across. This pegmatite is rare to absent in that portion of the complex in Raglan and Lyndoch Townships, and all but the eastern part of Brudenell Township. The pegmatite contains numerous coarse crystals of green, red, and brown apatite up to 30 cm long, amphibole and sodic pyroxene crystals and aggregates up to 1 m in size, titanite crystals up to several centimetres in size, potassic feldspar crystals up to 30 cm across, minor scapolite crystals, and some fluorite generally intergrown with calcite; zircon and biotite crystals are rarely present. All of these rocks were emplaced during the waning stages of regional metamorphism after rocks forming the bulk of the complex were emplaced, and they form an integral part of the complex suggesting that they are genetically related to the complex, particularly sodic pyroxene syenite and alkalic granite phases. Pyroxene veinlets and sodic pyroxene syenite pegmatite are also abundant in supracrustal rocks enveloping the complex and occurring as screens within the complex. A few occurrences of sodic pyroxene syenite pegmatite were mapped south of the complex in Lyndoch and southern Raglan Townships, but the pyroxene veinlets are confined to the complex and its immediate envelope of supracrustal rocks. Granite pegmatite dikes are also widespread throughout the Precambrian rocks of the map-area, but they are particularly abundant in the alkalic complex. Similar sodic pyroxene veinlets and syenite pegmatite bodies are typical products of fenitization associated with alkalic rock-carbonatite complexes within the Ottawa-Bonnechere Graben (Lumbers 1971) and are also developed in association with lenses of carbonatite cutting metasediments in Sullivan Island in Ottawa River, Westmeath Township (see "Alkalic Intrusive Rocks" below). Perhaps the veinlets and syenite pegmatites associated with the complex also reflect a late stage fenitization. Relative to the pyroxene veinlets, at least two generations of granite pegmatite are present because some of the veinlets cut this pegmatite, whereas others are cut by the pegmatite.

In the past, a few apatite-calcite pegmatites were mined for apatite, and they remain a major attraction for mineral collectors and mineralogists. Sodic pyroxene syenite pegmatite occurring south of Bruceton in the southwestern corner of Lyndoch Township contains coarse flakes of molybdenite up to 4 cm across and was mined in the early 1900s (No. 17, Map 2461, back pocket). Minor uranium mineralization is associated with pegmatitic and siliceous phases of the alkalic complex in Sebastopol Township (Themistocleous 1978).

Syenite-Monzonite Suite Intrusive Rocks

Rocks of the syenite-monzonite suite are mainly only partly deformed and recrystallized and were emplaced at a late stage relative to the high rank regional metamorphism. The suite is represented by only a few stocks in Brougham, Bagot, McNab, Admaston, and South Algona Townships. The largest stock is in Brougham Township. Most of the stocks are predominantly composed of medium- to coarse-grained, grey to pink, equigranular to porphyritic, leucosyenite and biotite syenite containing abundant mesoperthite and minor oligoclase. Phases containing ferrohastingsite and minor augite are present in many of the intrusions, together with minor monzonite and early tonalite, diorite, and gabbro. Syenites containing amphibole and pyroxene generally

contain xenoliths of skarn and calc-silicate rocks. Locally, within some of the intrusions, quartz is a minor to major consituent, and the syenites grade into quartz syenite and quartz monzonite. Titanite, iron-titanium oxide minerals, epidote, carbonate, muscovite, and zircon are common accessory minerals in the syenitic and granitic phases. A few of the stocks are cut by late granite pegmatite dikes (map-unit 27) suggesting that the suite is older than the late pegmatites.

The only mineralization associated with rocks of this suite consists of minor magnetite concentrations in skarn developed at the margin of the stock immediately east of Calabogie Lake in Bagot Township.

Late Mafic Intrusive Rocks

A few dikes of partly recrystallized and cataclastic metadiabase emplaced during the waning stages of the high rank regional metamorphism were mapped in various parts of the area, but mainly in the Late Precambrian supracrustal rocks. Preservation of relict primary mineralogy and textures modified by cataclasis in the dike rocks indicates that emplacement and deformation of the dikes occurred during cooling of the completely recrystallized host rocks during waning stages of regional metamorphism. The dikes are particularly abundant in Griffith Township where they cut rocks of the Burns Lake complex and the Griffith batholith. The age of the dikes relative to the late pegmatite dikes is unknown, but the two varieties of dikes could overlap in age because both varieties were emplaced during the waning stages of the high rank regional metamorphism.

Late Pegmatite

Late granite pegmatite dikes are abundant in all the gneisses of the map-area, but most of the dikes are small, lenticular bodies generally less than a few metres long and 1 m wide. They commonly formed in dilatant zones within the gneisses, and many of the dikes follow late open folds formed during uplift of the metamorphic complex after culmination of the late high rank regional metamorphism. A small proportion of the dikes are relatively large and are mainly spatially associated with older gneissic intrusive rocks. Large dikes up to tens of metres long and several metres across are relatively common in anorthositic and tonalitic rocks of the Algonquin Batholith, and a few of these dikes were mined for feldspar and mica. Large dikes are also present in mafic rocks of the biotite diorite suite, the anorthosite suite cutting the Late Precambrian supracrustal rocks, and in syenitic and granitic rocks of the alkalic suite. With few exceptions, the largest dikes, some of which can be traced along strike for nearly 3 km, are in carbonate-rich supracrustal rocks within less than 1 km of contacts of relatively large intrusive bodies, mainly rocks of the biotite diorite suite and the quartz monzonite suite. A major exception to this general mode of occurrence of the largest dikes is a 3 km long dike extending northward from Miller Lake in southeastern Admaston Township; this dike cuts siliceous metasediments, and the closest intrusive stocks or larger bodies are 2 km or more from the dike.

The dikes are composed of alkalic feldspar, quartz, and mica (mainly biotite, but abundant muscovite in some dikes) as the major constituents, and a large variety of accessory constituents, chief among which are amphibole, garnet, apatite, calcite, zircon, tourmaline, molybdenite, iron-titanium oxide minerals, pyrite, pyrrhotite, and traces of uranium and rare earth minerals. Graphic intergrowths of quartz and feldspar are common; some dikes are zoned with quartz-rich cores, and some dikes contain crystals of feldspar and micas up to 60 cm across. Most of the dikes are partly hematitized, which produces pink hues in the rock, but dikes in marble-rich sequences are generally white and lack hematitization. Rarely, some of the accessory constituents listed above are concentrated within the dikes. The large dike in southeastern Admaston Township contains abundant concentrations of tourmaline, and a few dikes near rocks of the biotite diorite suite in southeastern Raglan Township contain concentrations of uraninite and minor uranothorite associated with small biotite-rich patches and pyritic zones near the margins of the dikes. These dikes appear to contain the largest concentrations of uranium found to date in the map-area. Small concentrations of molybdenite occur in a few dikes, and beryl is concentrated in two dikes associated with alkalic granite of the alkalic suite near Quadeville in Lyndoch Township.

Field evidence suggests that the late pegmatite dikes were emplaced over an undefined interval of time during the waning stages of the high rank regional metamorphism. Some of the dikes are cataclastic, whereas others are massive and completely undeformed. Mention was made above of at least two generations of late pegmatite in the alkalic complex relative to the pyroxene veinlets. Elsewhere, intersecting pegmatite dikes were observed in a few places. Several late pegmatite dikes from various parts of the Grenville Province surrounding the map-area have been dated radiometrically (Shillibeer and Cumming 1956; Silver and Lumbers 1966) and although the ages are close to 1.0 ga, there is a spread which also suggests emplacement of the dikes over an interval, probably not exceeding a few tens of millions of years.

HIGH RANK REGIONAL METAMORPHISM

Most of the deformation and recrystallization displayed by the gneisses in the map-area can be attributed to the late high rank regional metamorphism which culminated about 1.1 Ga ago. Most likely, the supracrustal rocks were subjected to folding and low rank regional metamorphism prior to the high rank event; evidence for such a metamorphism is mainly confined to the Bancroft-Madoc area to the southwest of the map-area (Lumbers 1967). The intensity of the high rank metamorphism, measured in terms of both mineralogical and structural adjustments of the rocks to physical and chemical conditions which were imposed upon them at depth, varies throughout the area. The most highly metamorphosed rocks coincide with zones of low dipping to subhorizontal gneissosity, and the least metamorphosed rocks are found in zones with steeply dipping to subvertical gneissosity. From a mineral assemblage viewpoint, the gneisses were metamorphosed under the temperature and pressure conditions of the middle to upper almandine amphibolite facies; the only excep-

tion is the cordierite-bearing rocks of the biotite diorite suite along Ottawa River in Ross Township which contain mineral assemblages indicative of the granulite facies. Metamorphic mineral assemblages in the various gneisses seem to be largely controlled by the bulk composition of the rocks and the degree of strain exhibited by the rocks. Establishment of isograds using specific index minerals or mineral reactions would be difficult at best in the map-area. The difficulty of performing such an exercise is well illustrated by the marble-rich terrain in McNab Township where fine-grained marble showing relatively well preserved primary sedimentary structures is complexly intercalated with medium- to coarse-grained, coarsely recrystallized marble in which primary sedimentary structures are largely destroyed. Zones of low dipping to subhorizontal gneissosity contain highly strained rocks, and deformation may have promoted relatively higher heat flow than in zones of more steeply dipping gneisses which are less strained. As mentioned previously, the low dipping to subhorizontal gneissosity reflects recumbent folding related to diapirism of the Algonquin Batholith during the high rank metamorphism.

Various minerals of economic interest were formed in the metasediments as a result of the high rank metamorphism. Concentrations of graphite developed locally in the marbles, but unfortunately, the factors involved in controlling the concentration of graphite in these rocks are largely unknown. Garnet and sillimanite developed in shaly metasediments, and garnet is locally abundant in some of the gneissic intrusive rocks. Pyrite and graphite were concentrated in rusty schists, most of which developed at a late stage during the high rank metamorphism. Asbestos developed locally in siliceous dolomitic marble in response to shearing along fault zones. A variety of gneisses suitable for building stone were also produced by the high rank metamorphism, but to date, only some of the marbles have been exploited for this purpose.

INTRUSIONS ASSOCIATED WITH OTTAWA-BONNECHERE GRABEN

Alkalic Intrusive Rocks

Following the late high rank regional metamorphism, major faulting occurred along the Ottawa-Bonnechere Graben and several small intrusions were emplaced, mainly in the form of dikes localized along the faults. A gabbroic stock (described under "Mafic to Ultramafic Intrusive Rocks", below) and an alkalic rock-carbonatite complex also were emplaced within the graben.

The alkalic rock-carbonatite complex is exposed in the vicinity of Sullivan Island in Ottawa River, about 5 km south of La Passe, Westmeath Township. Most of the complex consists of partly fenitized clastic siliceous metasediments, mainly rocks of map-unit 6a. Fenitization is expressed as zones of intense hematitization localized by abundant fractures in which coarse-grained aggregates and crystals of alkalic amphibole, alkalic pyroxene, and alkalic feldspar have grown metasomatically. Small lenses of aegirine syenite pegmatite are associated with some of the fractures. Where fenitization is most intense, dike-like bodies of two main rock types are present: 1) pegmatitic aegirine syenite;

and 2) silicocarbonatite rich in silicate minerals and rounded fragments of fenite (Photo 11). Aegirine syenite consists mainly of coarsely perthitic potassic feldspar, aegirine, titanite, and minor amounts of garnet, pyrite, iron-titanium oxide minerals, sodic plagioclase, calcite, and biotite. A few irregularly shaped masses of very coarse-grained, dark grey to almost black calcite containing as much as 30 percent apatite crystals up to 1 cm long are associated with the syenite. The silicocarbonatite consists mainly of calcite, apatite, titanite, sodic pyroxene, amphibole, phlogopite, and perthitic potassic feldspar; biotite, allanite, pyrite, hematite, and iron-titanium oxide minerals are locally abundant. In places, lenses of carbonatite relatively poor in the above listed minerals but containing coarse crystals of brownish to red apatite are present in the carbonatite. Zircon as euhedral crystals up to 2 mm across is invariably present in the silicocarbonatite and carbonatite and forms up to 2 percent of these rocks. Rounded fragments in the silicocarbonatite consist mainly of highly fenitized metasediments, but fragments of fenitized granitic rocks and late granite pegmatite also occur. A few large granite pegmatite dikes cut the metasediments in the zone of fenitization and are also partly fenitized. The complex is therefore younger than the late pegmatite dikes, and preliminary geochronologic data by T.E. Krogh (Jack Satterly Geochronology Laboratory, Royal Ontario Museum, personal communication, 1978), on zircons from the silicocarbonatite indicate that this rock has a minimum age of about 1.05 Ga. A diabase dike cuts the southern part of the complex, and one silicocarbonatite dike contains

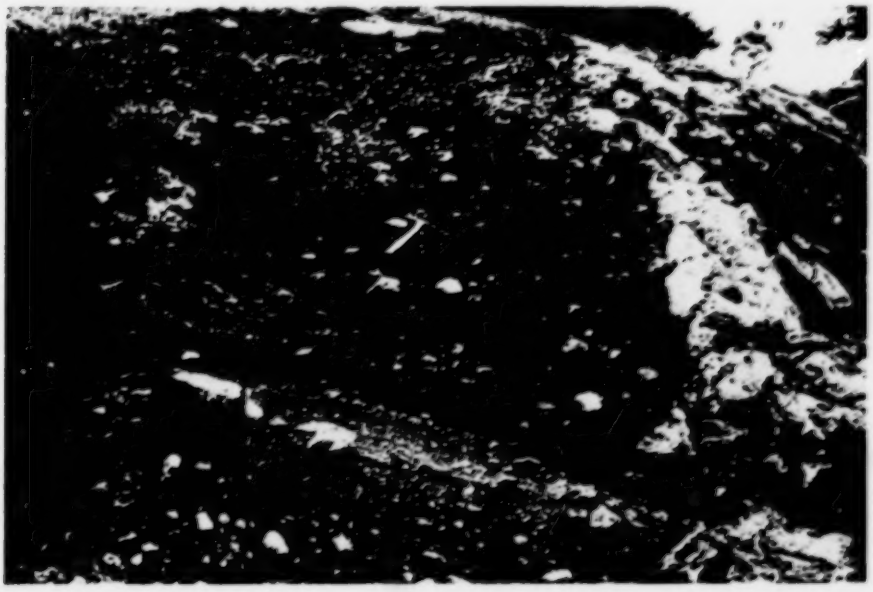

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Photo 11–Silicocarbonatite rich in silicate minerals and rounded fragments of fenite in contact with fenitized metasediments (on right side of photograph). Sullivan Island, Westmeath Township.

a few small mafic-rich dikes composed mainly of calcic plagioclase (An_{70}), lizardite and talc in part pseudomorphous after pyroxene, and iron-titanium oxide minerals. Minor uranium mineralization in pegmatitic aegirine syenite and fenite has been investigated by a few pits and trenches in the southern part of the complex.

Although the complex lies within the Ottawa-Bonnechere Graben which contains several widely scattered alkalic rock-carbonatite complexes (see Figure 4), it is also spatially associated with the complex of alkalic suite intrusive rocks. This spatial association plus the widespread fenitization in the alkalic complex in the form of sodic pyroxene veinlets suggests that the Sullivan Island complex may be related to the alkalic complex.

Mafic to Ultramafic Intrusive Rocks

The Chenaux gabbro in Horton and Ross Townships is dominated by partly uralitized gabbro consisting of labradorite and clinopyroxene with accessory iron-titanium oxide minerals, apatite, and, rarely, traces of quartz. Locally, the gabbro contains coarse-grained, pegmatitic patches containing coarse-grained intergrowths of sodic plagioclase, amphibole, and minor quartz. The pegmatitic patches are widespread throughout the body, but are particularly abundant near the margins. The pyroxene content of the gabbro varies throughout the body, so that in places the rocks are anorthositic, and in other places they display igneous layering with alternating gabbro, anorthositic, and pyroxene-rich layers. Dikes and irregularly shaped masses of uralitized pyroxenite cut the gabbro locally and contain minor concentrations of pyrite, pyrrhotite, pentlandite, and chalcopyrite. A few dikes of medium- to coarse-grained, porphyritic quartz monzonite and syenite cut the gabbro near the margin of the body. Small, irregular zones of skarn rich in diopside, epidote, and amphibole are common at contacts between the intrusion and the enveloping marbles.

A small intrusion of partly uralitized and serpentinized peridotite containing accessory tiny crystals of light blue spinel occurs about 5.5 km west of the Chenaux gabbro in the northeast corner of Admaston Township. The peridotite intrusion cuts marble and is exposed over a width of less than 90 m.

Diabase dikes are common both along, and nearby, the various faults of the Ottawa-Bonnechere Graben north of the Mount St. Patrick and Arabis Lake Faults. Only a few diabase dikes are present to the south of these faults. The diabase is tholeiitic and consists of oscillatory zoned andesine-labradorite, calcic clinopyroxene and pigeonite, minor iron-titanium oxide minerals, biotite, and apatite, and rare interstitial quartz in graphic intergrowth with plagioclase. Some dikes contain a few olivine grains armoured by clinopyroxene. Pyroxene and olivine are slightly altered; the chief secondary minerals are amphibole, serpentine, biotite, and carbonate. A few dikes are sheared and brecciated by post-dike faulting.

A few highly hematitized trachyte dikes dominated by alkalic feldspar were mapped near Calabogie Lake in Bagot Township, and along Barron River in the northeast corner of Master Township. These dikes are tentatively assigned to the Cambrian because similar dikes to the north of the map-area are known to be Cambrian in age (Lumbers 1971; 1976a).

Paleozoic

Ordovician Sedimentary Rocks

Paleozoic sedimentary rocks are preserved as downfaulted outliers within the Ottawa-Bonnechere Graben. The rocks are subdivided lithologically, rather than by formations, because their stratigraphy has not been established unequivocally. The oldest unit consists of Lower Ordovician yellow to brown, silty dolostone containing minor partings and interbeds of shale. A few lenses of quartz-pebble conglomerate occur at the base of the unit. Rocks of this unit are exposed only in the vicinity of Arnprior in McNab and Fitzroy Townships and east of Pembroke on the north side of Cotnam Island near Highway 62. A second unit, not in contact with the first, consists of Middle Ordovician green and red shale and siltstone locally with intercalated cross-bedded quartz sandstone. Near the base of the unit, lensoid beds of green glauconitic sandstone and quartz-pebble conglomerate are present. The unit is exposed near Arnprior along Ottawa River in McNab Township and along Ottawa River near Pembroke. The unit is overlain by Middle Ordovician grey fossiliferous bioclastic limestone containing minor dark grey to black shale partings and interbeds. Interbeds of buff dolostone are rarely present in the limestone, and calcareous quartz sandstone is present near the base. A disconformity may separate the shaly unit from the limestone unit. The limestone unit accounts for all the exposures of Paleozoic sedimentary rocks inland from Ottawa River.

Late Fissure Veins

Late fissure veins of three main types cut both the Precambrian and Paleozoic rocks in the southeastern part of the map-area southeast of Calabogie Lake, in the vicinity of White Lake, and in McNab and Fitzroy Townships. The fissure veins southeast of Calabogie are composed mainly of dolomite and barytocelestite, whereas those in the vicinity of White Lake are hematite-rich. In McNab and Fitzroy Townships, calcite-barite fissure veins locally containing concentrations of galena, sphalerite, fluorite, and hematite are present. Veins of this type were mined for galena at the Kingdon mine (No. 15 on Map 2462, back pocket) north of galetta in Fitzroy Township.

SUMMARY OF THE MINERALIZATION

Mineralization related to the various events recorded by rocks of the map-area is summarized in Figure 5, and the distribution of the various deposits is shown on Maps 2459, 2460, 2461, and 2462 (back pocket). Detailed description of the deposits are given by Satterly (1945), Quinn (1952), Hewitt (1954), Carter *et al.* (1979), Gordon and Masson (in prep.), and Vos and Storey (1979). In Figure 5, mineralization shown in brackets does not occur in the map-area but

is known to be present to the southwest in the Bancroft-Madoc area (Lumbers 1964; 1967). Concentrations of iron associated with faults of the Ottawa-Bonnechere Graben are present in the North Bay area (Lumbers 1971).

Although a large variety of mineral deposits are present in the area, available data suggest that only a few of the deposits are of current economic interest. Nevertheless, the available data are scanty, and much more data, particularly on the mineralogy and chemistry of the deposits and their associated rocks, are needed to properly assess the mineral potential. The present study provides a geological framework for collecting the additional data.

Base Metal Mineralization

COPPER AND NICKEL

Concentrations of copper and nickel are confined mainly to mafic intrusive bodies of the biotite diorite suite and the Chenaux gabbro. Copper and nickel deposits in these intrusions appear to be magmatic segregations developed in mafic gabbro and pyroxenite phases. Of the various mafic intrusive bodies of the biotite diorite suite in the map-area, only the Raglan Hills body is known to contain magmatic segregation copper-nickel deposits. Such deposits are also known in dioritic intrusions of the suite southwest of the map-area, and from studies of these deposits, the author concluded that trace element analyses of magnetic opaque fractions from gabbro and dioritic phases may prove useful in indicating the presence or absence of copper and nickel concentrations in associated mafic gabbro and pyroxenite phases (Lumbers 1964; 1969). Mineralogically, the deposits are dominated by disseminated chalcopyrite, pyrrhotite, pentlandite, and minor to locally abundant pyrite. Cubanite and sphalerite occur in trace amounts, and chalcopyrite is generally much less abundant than pentlandite and the iron sulphide minerals.

Two small bodies of copper and minor zinc and iron mineralization in the form of disseminated to massive chalcopyrite, sphalerite, and magnetite are associated with amphibolite near the margin of the Slate Falls complex at the southern boundary of Lyndoch Township. Some of the amphibolite may be derived from mafic metavolcanics, but some is derived from gabbro and diorite. Further work is required to determine if the deposits are related to the complex or to some other event, such as mafic volcanism. Minor copper mineralization in the form of sparsely to locally abundant disseminated chalcopyrite is present in some skarns associated with the alkalic complex and rocks of the biotite diorite suite. Sparsely disseminated chalcopyrite also occurs in some of the rusty schist units developed in various parts of the map-area.

In summary, present data indicate that the mafic intrusions of the biotite diorite suite and the Chenaux gabbro are the most favourable units for the discovery of copper and nickel deposits in the map-area.

IRON AND TITANIUM

Concentrations of iron in the map-area occur as 1) contact metasomatic deposits associated with mafic intrusions of the biotite diorite suite and the alkalic suite, and, rarely, rocks of the syenite-monzonite suite; 2) magmatic segregations in gabbro of the biotite diorite suite and in the Chenaux gabbro; 3) concentrations of magnetite associated with alkalic granite of the alkalic suite; 4) iron formation associated with Middle and Late Precambrian metasediments; and 5) hematite-rich fissure veins. The largest concentrations are developed in contact metasomatic deposits at the margins of mafic intrusions of the biotite diorite suite and the alkalic suite. Iron concentrations in alkalic granite occur as magnetite-rich lenses known only at the Radnor mine (No.19, Map 2462, back pocket) in Grattan Township and as abundant accessory magnetite in some units of alkalic granite, particularly in southeastern Brudenell and Sebastopol Townships.

Concentrations of titanium are rare in the map-area. Much of the alkalic syenite of the alkalic suite and silicocarbonatite of the alkalic rock-carbonatite complex in Sullivan Island are relatively rich in accessory titanite. Small, locallized magmatic segregation iron deposits in gabbroic rocks of the biotite diorite suite and Cheneaux gabbro are dominated by ilmenomagnetite and contain traces of vanadium. Titanite is also concentrated locally in some skarns and calcite-rich pegmatites associated with the alkalic complex. These various rocks contain the largest concentrations of titanium known in the map-area, and all are too small and too low grade to be of current economic interest.

LEAD

Concentrations of lead are known only in late calcite-barite fissure veins confined to marble-rich terrains in McNab and Fitzroy Townships. Galena is the chief lead mineral and is generally accompanied by small amounts of sphalerite, hematite, pyrite, barytocelestite, fluorite, and quartz. Traces of a variety of sulphosalt minerals are present in some of the veins and the galena is commonly argentiferous. The veins appear to be locallized along faults related to the Ottawa-Bonnechere Graben, and they show most of the features described by the author for late calcite and quartz fissure veins to the southwest of the map-area (Lumbers 1964; 1969). Two of the veins were mined for lead (Kingdon mine, No. 15, Map 2462, back pocket) but most of the known veins are too small and poorly mineralized to be of economic interest. Nevertheless, rock exposure is poor in the marble-rich terrains favourable for the veins, and many others could be present but not exposed. The veins therefore remain as a potential source of lead, if efficient exploration techniques can be devised to locate them.

MOLYBDENUM

Molybdenum, occurring as molybdenite, is concentrated mainly in skarns and pyritic zones developed at contacts between marble and trondhjemite-rich

intrusions of the biotite diorite suite and between marble and late granite pegmatite dikes. Traces of molybdenite are common within the late granite pegmatite dikes, but relatively rare in the late sodic pyroxene syenite pegmatite dikes of the alkalic suite. Nevertheless, one syenite pegmatite dike (McCoy mine, No.17, Map 2461, back pocket) contains numerous large flakes of molybdenite. The skarn deposits offer the best potential for mineable concentrations of molybdenite, but work on several such deposits to date has failed to reveal sufficient tonnages of ore grade material.

ZINC

Zinc mineralization in the form of sphalerite occurs in association with copper and nickel mineralization, in some of the calcite-barite fissure veins, and in dolomitic marble southwest of Renfrew in Admaston Township. Of these three main occurrences of zinc mineralization, that in dolomitic marble in Admaston Township has the greatest economic potential. The zinc mineralization is in layers conformable with gneissic layering in the host marble and lies on strike between two thin units of metavolcanics. Locally, the dolomitic marble contains relict chert beds. The mineralization, which is similar to that of the Balmat-Edwards district of New York State (Lea and Dill 1968) within the Late Precambrian carbonate basin, perhaps formed during sedimentation and volcanism. Moreover, the association of zinc and lead mineralization with cherty dolomitic carbonate rocks of both Precambrian and Phanerozoic age is well established. Thus, other main units of dolomitic marble present in the map-area are indicated by separate codes on the accompanying maps (Maps 2460, 2461, 2462, back pocket) and these should be examined for possible concentrations of sphalerite and galena.

Precious Metals

Concentrations of precious metals of possible economic importance appear to be lacking within the map-area. Trace amounts of gold have been reported from a few quartz veins, and minor silver is associated with the late calcite-barite fissure veins. To the south and southwest of the map-area, gold and silver concentrations of possible economic importance are known in late fissure veins and in calcite and quartz veins (Lumbers 1964). The main area of gold mineralization within the Late Precambrian carbonate basin is confined to the low metamorphic rank terrain between Bancroft and Madoc characterized by thick deposits of mafic metavolcanics (Lumbers 1964). Most of the gold mineralization is in quartz-rich veins in metavolcanic sequences near the margins of intrusive rocks of the biotite diorite suite.

Uranium and Rare Earth Mineralization

Uranium and rare earth mineralization is widespread throughout the map-area, but most of the known occurrences are small and not of economic importance. On the accompanying maps (back pocket), only those occurrences are shown that contain at least local concentrations of uranium and rare earth minerals. Occurrences containing traces of radioactive minerals that are merely of mineralogical interest are omitted. Such occurrences are abundant, and a high probability exists that a detailed search of almost any late granite pegmatite dike would reveal a crystal or two of radioactive minerals. All the occurrences shown are within the Late Precambrian accumulation south of the Algonquin Batholith. Most of the occurrences are in late granite pegmatite dikes, but some are associated with: 1) late phases of the alkalic complex (mainly sodic pyroxene syenite pegmatite, granite pegmatite, and calcite-rich pegmatite); 2) the alkalic rock-carbonatite complex in Sullivan Island; 3) skarns associated with late phases of the alkalic complex; 4) skarns associated with late granite pegmatite dikes; and 5) rarely in late fault zones. Traces of uranium mineralization are common in the various molybdenite deposits developed in association with late granite pegmatite dikes and skarns. Field evidence therefore shows that the uranium and rare earth mineralization was formed late in the plutonic and metamorphic history of the area, and radiometric age determinations on uranium-rich minerals confirm this conclusion (Shillibeer and Cumming 1956).

Within the Algonquin Batholith and the Middle Precambrian metasediments, uranium and rare earth mineralization is confined to late granite pegmatite bodies. Radioactive minerals within the various pegmatites are mainly uranium-bearing rare earth species such as euxenite, allanite, fergusonite, and aeschynite. Thorite and monazite are present in some dikes, but uraninite and uranothorite, which are common in occurrences south of the Algonquin Batholith within the Late Precambrian accumulation, are relatively rare.

An airborne gamma-ray spectrometry survey covering the map-area (GSC 1976) revealed several areas of anomalously high uranium and thorium concentrations within the Late Precambrian accumulation. These areas are 1) centered over the quartz monzonite body on the western side of Calabogie Lake; 2) centered over the Hurds Lake trondhjemite; 3) along the Miller-South Canonto Townships boundary; 4) centered over the quartz monzonite body in Blithfield Township, about 3 km southwest of Mile Lake; 5) centered over the region containing the Hunt mine (No. 12) in Brougham Township; and 6) that portion of the alkalic complex rich in alkalic granite northeast and southwest of Lake Clear. Most of the anomalies are of low intensity, but the anomaly along the Miller-South Canonto Townships boundary is relatively intense. The anomaly lies just south of the map-area and is underlain mainly by gneissic quartz monzonite containing abundant granite pegmatite dikes according to mapping by Smith (1958). The various anomalies appear to be caused mainly by minor uranium and thorium mineralization in local concentrations of late granite pegmatite dikes and in skarns spatially associated with concentrations of these dikes. The mineralization is mainly in uraninite and uranothorite, but traces of uranium-bearing rare earth minerals are common, especially in oc-

currences spatially associated with the alkalic complex. Uranium is also concentrated in late granite pegmatite dikes not revealed by the airborne survey, and work to date suggests that the greatest concentrations of uranium and thorium in the map-area are in relatively large granite pegmatite dikes developed in marble-rich supracrustal rocks near the margins of biotite diorite suite intrusions. In all the pegmatite dikes, the best uranium mineralization is invariably associated with local concentrations of biotite, local pyritic zones, or local concentrations of magnetite, all of which are most commonly developed near the margins of the dikes.

Allanite is a common accessory constituent in alkalic syenite and granite of the alkalic complex, and rarely, the alkalic granite contains traces of uraninite and uranothorite. These minerals are most common in pegmatitic portions of the alkalic granite, especially where the granite contains alkalic pyroxene and local alkalic syenite phases. The alkalic complex extends southwestward beyond the map-area into the Bancroft area where the largest concentrations of uranium and thorium minerals known in the Grenville Province of Ontario (Satterly 1957) are spatially associated with phases of the complex. Further work is required to determine if the mineralization is genetically related to the complex. Moreover, factors controlling both the concentration of uranium and thorium in the various deposits and the formation of the common host pegmatites and associated skarns are largely unknown. Knowledge of these factors would greatly aid in the exploration of known deposits and in the search for new deposits.

The coarse clastic sequence at the base of the Late Precambrian accumulation represents a major unconformity, and such an environment can be favourable for the concentration of uranium. Assessment of this sequence for possible uranium concentrations must await further regional mapping and detailed petrologic and geochemical studies. Nevertheless, it remains a potential target for uranium exploration.

Other Metallic Mineralization

Other metallic mineralization within the map-area consists of beryllium, magnesium, and zirconium. Beryllium and zirconium mineralization are confined to the alkalic complex. Beryl occurs in two zoned granite pegmatite bodies enclosed within alkalic granite in Lyndoch Township (No. 5, Map 2461, back pocket) and is currently mined, chiefly for the lapidary trade. No other concentrations of beryl have been found in the alkalic complex. Trace amounts of lyndochite, columbite, columbian anatase, cyrtolite, monazite, and euxenite accompany the beryl in the pegmatites (Hewitt 1954). Although traces of zirconium, in the form of zircon, are present in most of the plutonic rocks, pegmatites, and some of the metasediments of the map-area, the only concentrations are in late syenite and calcite-rich and syenite pegmatites of the alkalic complex; some of the carbonatite in Sullivan Island also contains abundant accessory zircon. All of the concentrations appear to be too small to be utilized as a source of zirconium, but one occurrence at the eastern end of Kuehl Lake in Brudenell Township contains scattered zircon crystals up to 7 cm long, some of which are of good hyacinth colour suitable for facetting.

Magnesium is produced by Chromasco Limited from dolomitic marble in Ross Township (No. 2, Map 2460, back pocket). The dolomitic marble mined by Chromasco is relatively free of siliceous impurities, and other parts of the unit have been utilized in the past for use as dimension stone and crushed aggregate.

Non-Metallic Mineralization

DEPOSITS ASSOCIATED MAINLY WITH THE ALKALIC COMPLEX

Most of the known concentrations of apatite and fluorite, and all the concentrations of corundum and nepheline are found in the alkalic complex. Although apatite is a common accessory mineral in most of the rocks of the map-area, the only concentrations are in calcite-rich pegmatites of the alkalic complex and in carbonatite in Sullivan Island which is possibly related to the alkalic complex. Fluorite is also locally concentrated in calcite-rich pegmatites, but it also occurs as an accessory constituent in skarns, nepheline syenite, alkalic granite, and some of the late calcite fissure veins. Present data suggest that the apatite- and fluorite-bearing calcite pegmatites are too scattered and small to be mined for apatite and fluorite.

Corundum occurs in gneissic, albite-rich syenite and pegmatitic syenite, gneissic nepheline syenite, and gneissic anorthosite of the alkalic complex. The corundum formed during deformation and recrystallization of these rocks and is commonly concentrated in narrow layers as barrel-shaped to tapered crystals up to several centimetres long. The known corundum occurrences have proved to be too small and scattered to be mined profitably. Most of the past production comes from the Craigmont mine (No. 11, Map 2461, back pocket) in the northwest corner of Raglan Township (Satterly 1945).

None of the known occurrences of nepheline syenite and nepheline syenite pegmatite are of sufficient purity and size to be of current economic interest. Some of the larger occurrences have been explored, but no production has resulted (Satterly 1945; Hewitt 1961).

ASBESTOS

Asbestos, in the form of fibrous tremolite, is confined to siliceous dolomitic marble that underwent shearing along fault zones. The asbestos occurs as slip-fibre in veins from 1 mm to 5 cm in width. The fibres rarely exceed about 6 cm in length. A minor amount of asbestos was mined from one occurrence in lot 22, concession IV, Blithfield Township (Hewitt and Satterly 1953), but none of the occurrences appear to be of current economic interest because of their small size and confinement to narrow fault zones.

BARITE AND CELESTITE

Barite and celestite are confined to the late fissure veins. All the known veins contain only minor amounts of barite of no commercial interest. One fissure vein in lot 27, concession X, Bagot Township, consists mainly of dolomite, celestite, and minor calcite. The celestite is relatively rich in barium, and minor amounts of this mineral have been mined for use as a filler in the print, paper, and rubber trades with poor results (Satterly 1945).

FELDSPAR AND MICA

Some of the larger late granite pegmatite dikes have been mined for feldspar and mica, with quartz as a by-product. Most of the production has been achieved from dikes cutting anorthosite and related mafic rocks of the Algonquin Batholith. Phlogopite was mined from a narrow vein up to 18 cm wide in rusty schist associated with marble in lot 2, concession IV, Brougham Township. Rose quartz is produced from the beryl-bearing pegmatite dike in lots 30 and 31, concession XV, Lyndoch Township by Wal Gem Lapidary Company.

GRAPHITE

Graphite is a common accessory constituent of the marbles and rarely forms small massive lenses within these rocks. An exceptionally large concentration of graphite at the Black Donald mine (No.8, Map 2462, back pocket) was the only source of high quality flake graphite in North America until the mine closed due to flooding. The graphite zone is 1.5 to 1.8 m thick and is conformable with relict bedding in host intercalated calc-silicate metasediments and dolomitic and calcitic marbles. The origin of the graphite zone is unknown, and no comparable graphite concentration has been found in the map-area.

Since the closing of the Black Donald mine, the only producer of high-purity graphite in North America is the Southwest Graphite Company whose deposit is in Barnet County, Texas (Barnes 1958; Dietrich and Lonsdale 1958; Zaffarano *et al.* 1972). The deposit consists of a rusty schist unit, similar in all major aspects to rusty schist units within the map-area, and is developed in metasediments at the margin of a granitic pluton, a setting also common to most of the largest rusty schist units within the map-area. Both the rusty schist and the host rocks are in the Llano Uplift, a Precambrian inlier consisting of supracrustal and plutonic rocks comparable in age to those of the Late Precambrian accumulation of the map-area and probably forming an extension of the Grenville Province of the Canadian Shield (Barnes *et al.* 1972). The supracrustal rocks in the vicinity of the deposit are dominated by intercalated marble and calcareous and siliceous shaly metasediments much like those of the map-area, but less metamorphosed. In both the rusty schist of the deposit and the rusty schists of the map-area, graphite is relatively fine-grained (rarely forming flakes more than 10 mm across) and generally forms no more than 10 to 15

percent of the rock. Local concentrations of massive graphite along shears or in highly strained portions of minor folds are common. Because of the close similarities of the rusty schists of the map-area and the Texas deposit, consideration should be given to exploration of the map-area rusty schists for their graphite content.

The only other rock in the map-area known to contain concentrations of graphite is an exceptionally uncommon occurrence in massive alkalic syenite found by the author just east of Reid Lake in west-central Brudenell Township. The syenite consists mainly of primary, igneous mesoperthite and minor biotite with up to about 10 percent graphite flakes as much as 1.5 cm across, intergrown with the mesoperthite, both along grain boundaries and in fractures. The size of the graphitic syenite is unknown, but it appears to be worthy of exploration.

NEPHELINE SYENITE

Several small bodies of nepheline syenite and nepheline syenite pegmatite are associated with the alkalic complex. Petrographic data indicate that none of these bodies are suitable for the glass, ceramic, or mineral filler industries.

STONE

Several quarries have been operated at various times in the area to obtain stone for the manufacture of lime, building stone, and road metal. Over half the quarries are in Middle Ordovician limestone, and most of the remainder are in Precambrian marble. A few quarries have been opened in the Precambrian gneissic plutonic rocks and siliceous metasediments for road metal. The Middle Ordovician limestone is locally relatively pure containing from 2 to 3 percent $MgCO_3$ (Gouge 1938; Hewitt 1964), and it has been used for making lime. Currently, the limestone is quarried for crushed aggregate. Precambrian calcitic marble has been used for making lime, but this marble generally contains at least 5 percent $MgCO_3$ and variable amounts of siliceous impurities mainly concentrated in relict beds. The thickest and most abundant sequences of calcitic marble relatively free of siliceous impurities are in the marble-rich terrains in McNab Township and in the vicinity of Leclaire Lake in Matawatchan and Brougham Townships. Elsewhere, the calcitic marble is mainly siliceous with only local thin units relatively free of siliceous impurites. The thickest units of dolomitic marble relatively free of siliceous impurities are in Ross Township. Most of the marble quarried for building stone has been white, coarsely recrystallized dolomitic marble low in siliceous impurities because this marble is less friable and wears better than coarsely recrystallized white calcitic marble. Moreover, thick sequences of white calcitic marble low in impurities and suitable for quarrying are rare or absent.

No attempt has been made to utilize the various Precambrian gneisses as an ornamental and building stone. Some of these gneisses could prove suitable for these purposes because the complex metamorphic and tectonic history produced several varieties of the gneisses, particularly the plutonic rocks, that

take a good polish and have interesting combinations of colours and textures. Gneissic plutonic rocks similar to some of those in the map-area are quarried elsewhere outside Ontario and marketed in Canada's large urban centers. The only massive plutonic rock in the area with consistent colour and texture is the McArthurs Mills pluton at the extreme southwestern corner in Mayo and Ashby Townships.

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